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PHYSICAL/CHEMICAL TREATMENT
OF COKE PLANT WASTEWATER

By
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Contract No. 68-02-2671

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17. KEY WORDS AND DOCUMENT ANALYSIS

a. DESCRIPTORS		b. IDENTIFIERS/OPEN ENDED TERMS	c. COSATI Field/Group	
Pollution	Filtration	Pollution Control	13B	07D
Waste Water	Activated Carbon	Stationary Sources		11G
Coking	Sodium Sulfites	Alkaline Chlorination	13H	
Physical Tests	Dechlorination	Sodium Bisulfite	14B	07A
Chemical Tests	Cyanides			
Chlorination	Organic Compounds		07C,07B	

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ABSTRACT

The report documents a pilot-plant investigation of the applicability of advanced waste treatment methods for upgrading metallurgical cokemaking wastewaters to Best Available Technology (BAT) levels. Mobile treatment facilities, designed to operate at a flow rate of 19 liters/min (5 gpm), were used. Two physical-chemical treatment trains were investigated during the study; namely, a) alkaline chlorination-filtration-activated carbon and b) alkaline chlorination-sodium bisulfite dechlorination-filtration. For each treatment investigated, samples and operational data were obtained for later use in assessing and comparing the adequacy of the treatment. Toxic pollutant samples were collected from each treatment scheme investigated. Chlorination was effective in consistently reducing pollutant concentrations to below BAT levels with the exception of total cyanide. Filtration was determined to be essential as an adjunct to alkaline chlorination for post-treatment suspended solids removal. Activated carbon and sodium bisulfite were efficient in removing excess chlorine resulting from treatment by alkaline chlorination, although carbon was more effective in removing organic priority pollutants.

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SECTION 1

INTRODUCTION

PROJECT PURPOSE

The purpose of this project was to investigate the effectiveness of selected advanced waste treatment technologies for treating By-Product Cokemaking Subcategory wastewater to Best Available Technology (BAT)* Economically Achievable levels. The wastewaters generated from the by-product recovery process include excess ammonia liquors, benzol plant wastes, final cooler wastewaters, desulfurizer wastes, scrubber blowdown, and tar decanter wastewaters. Pollutants contained in these wastewaters typically include suspended solids, ammonia, phenolic compounds, cyanide, sulfide, oil and greases as well as many toxic pollutants. The plant investigated had an operating treatment system that included a free and fixed ammonia still and a dephenolizer. This degree of pretreatment is expected to be required prior to a BAT physcial/chemical treatment scheme (1).

The investigation was conducted using the U.S. Environmental Protection Agency's (EPA's) mobile physical-chemical treatment system. This pilot plant is housed in two semi-trailer vans as shown in Figures 1 and 2. The pilot equipment used for this study included the four chamber rapid mix tanks (alkaline chlorination) with the chemical feed system, the dual media filter skid, and the activated carbon columns.

The advanced waste treatment trains that were investigated on a pilot scale included the following:

1. ACL + FIL + AC
2. ACL + SBD + FIL

Key

AC: activated carbon
ACL: alkaline chlorination
FIL: dual media filtration
SBD: sodium bisulfite dechlorination

---

*Note: Because the development of final effluent limitation guidelines was underway during the time of this study, the reference BPT and BAT pollutant parameters used throughout this report are those listed in "Development Document For Proposed Effluent Limitations Guidelines and Standards for the Iron and Steel Manufacturing Point Source Category - Vol. II, By-Product Cokemaking Subcategory, October, 1979, EPA 440/1-79-02400 (1).

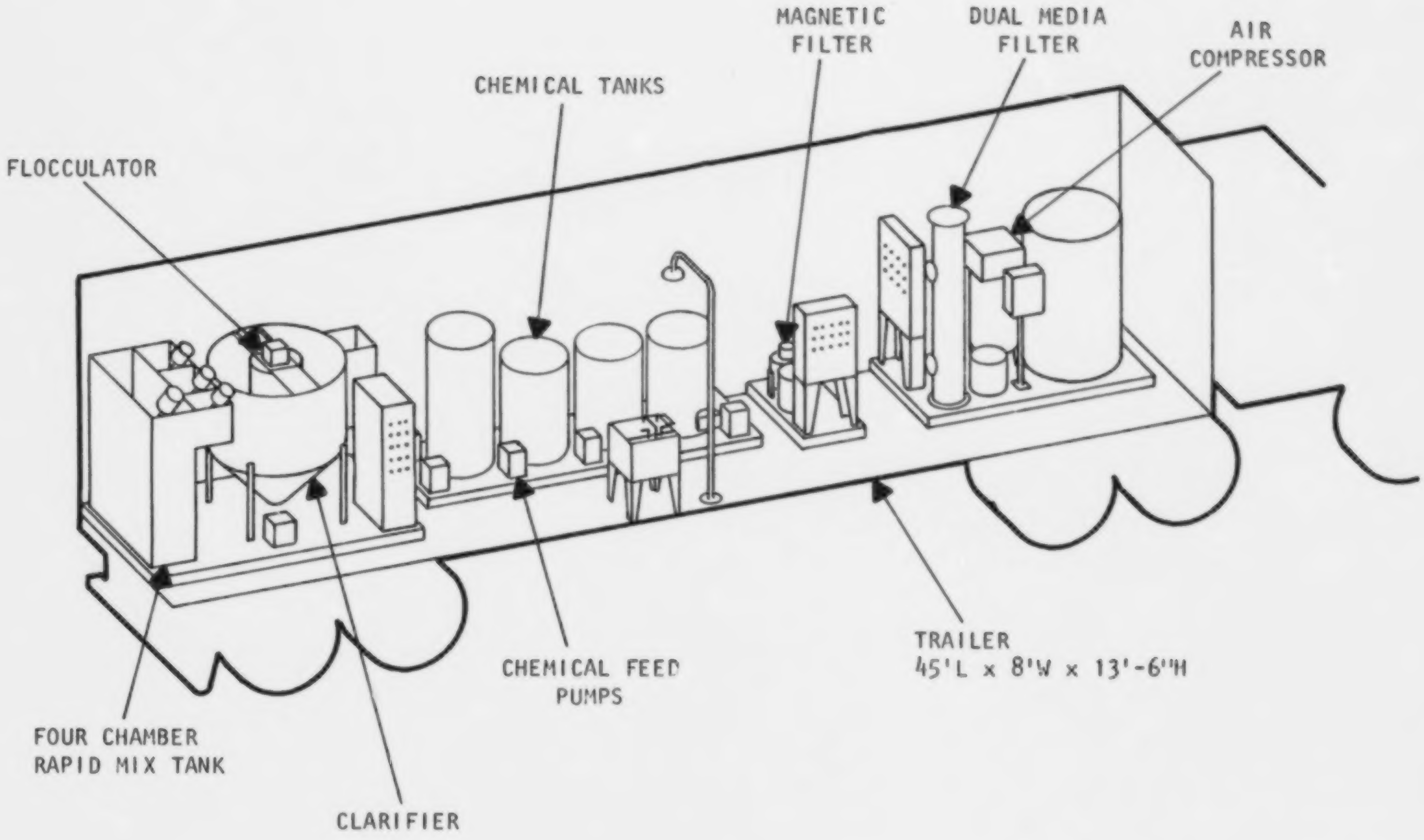

MAGNETIC FILTER
DUAL MEDIA FILTER
AIR COMPRESSOR
CHEMICAL TANKS
FLOCCULATOR
TRAILER
45'L x 8'W x 13'-6"H
CHEMICAL FEED PUMPS
FOUR CHAMBER RAPID MIX TANK
CLARIFIER

Figure 1. Steel plant mobile treatment system-trailer No. 1.

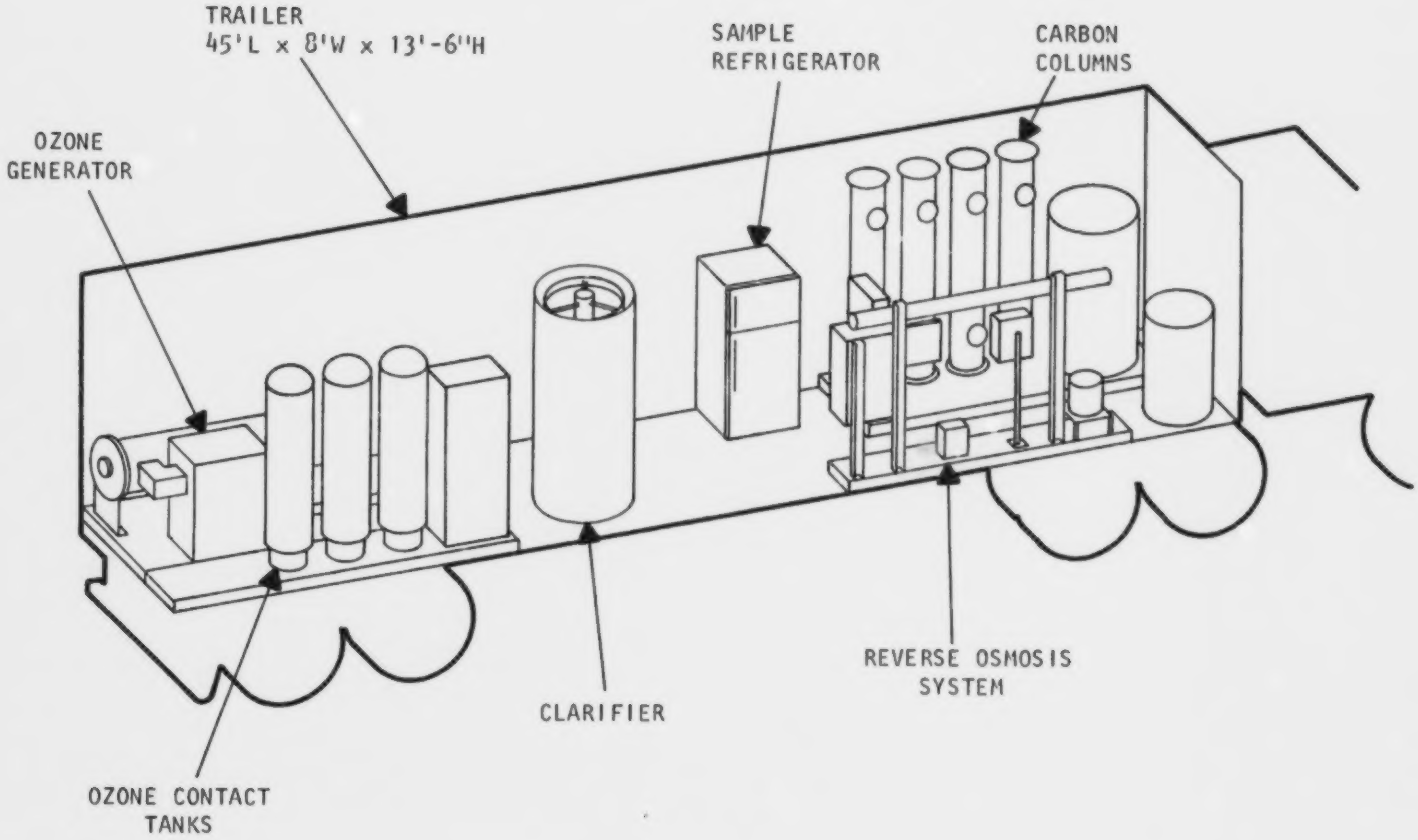

TRAILER
45'L × 8'W × 13'-6"H
SAMPLE REFRIGERATOR
CARBON COLUMNS
OZONE GENERATOR
CLARIFIER
REVERSE OSMOSIS SYSTEM
OZONE CONTACT TANKS

Figure 2. Steel plant mobile treatment system-trailer No. 2.

In the first pilot treatment train, the coke plant pre-treated wastewater was passed through a two stage alkaline chlorination process for cyanide, phenol, sulfide, thiocyanate and ammonia removal. The wastewater was then filtered for suspended solids removal and dechlorinated on activated carbon. The second treatment train again consisted of alkaline chlorination which was followed by sodium bisulfite dechlorination and dual media filtration. The treatment train arrangements are shown below in Figure 3.

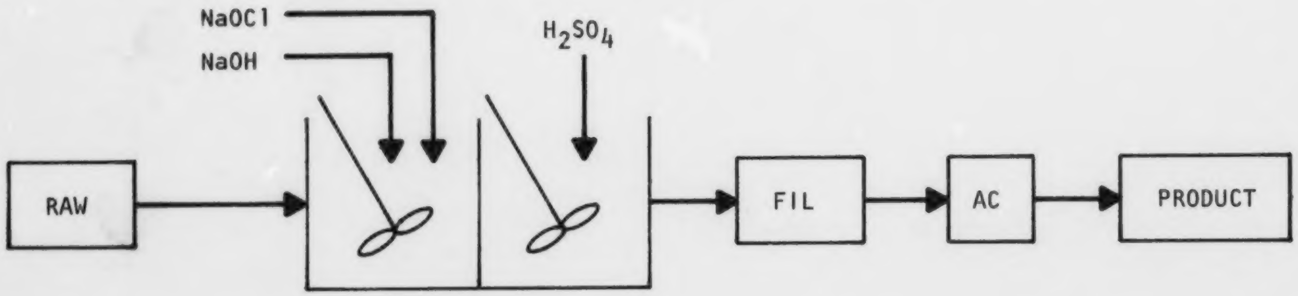
Prior to conducting the pilot studies, in-depth bench tests were performed to obtain preliminary information on treatment feasibility, expected magnitude of treatment efficiency and optimum treatment train process element arrangement.

During the pilot study, samples were collected for both conventional and toxic pollutants. Operational data were also recorded on a daily basis to evaluate the effectiveness of the respective treatment trains. The pilot study results were evaluated using the three primary criteria listed below:

1. process and/or treatment train performance
2. capital and annualized costs
3. space requirements

The forthcoming sections of this report discuss in detail the findings of this pilot scale investigation. An individual section has been prepared for each technology investigated to discuss results, operational problems and full-scale system cost and space requirements. The Section 2 Summary and Evaluation combines the individual process findings into treatment schemes capable of producing an effluent which meets BAT requirements. Raw data obtained during the pilot study are included as part of the Appendix.

(1) ALKALINE CHLORINATION, FILTRATION, CARBON ADSORPTION


NaOCl
NaOH
H_2SO_4
RAW
FIL
AC
PRODUCT

(2) ALKALINE CHLORINATION, SODIUM BISULFITE DECHLORINATION, FILTRATION

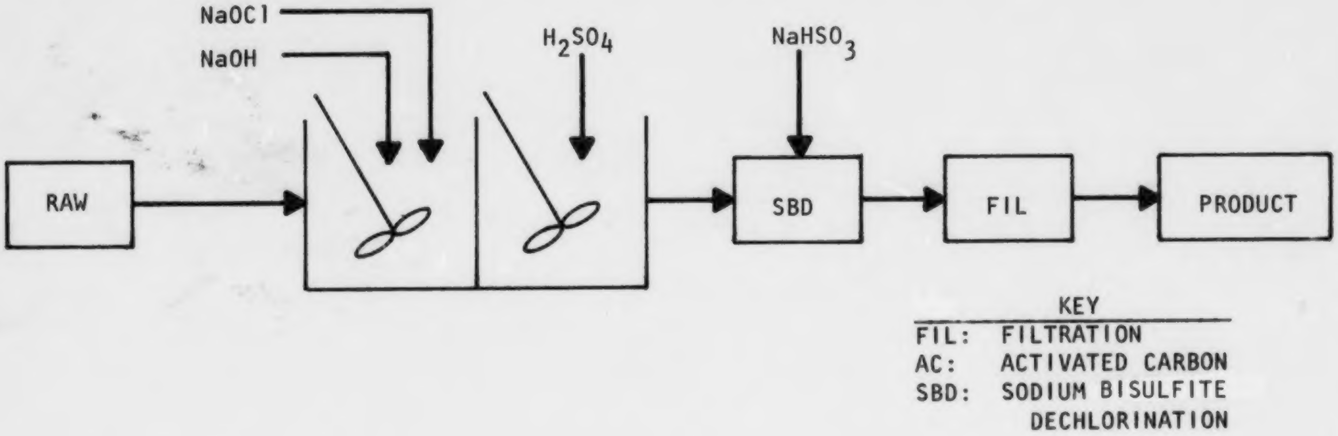

NaOCl
NaOH
H_2SO_4
$NaHSO_3$
RAW
SBD
FIL
PRODUCT
KEY
FIL: FILTRATION
AC: ACTIVATED CARBON
SBD: SODIUM BISULFITE DECHLORINATION

Figure 3. Process trains investigated for treatment of by-product coke plant wastewater.

SECTION 2

SUMMARY AND EVALUATION

EXPERIMENTAL RESULTS

General

The physical-chemical investigation on Shenango's by-product cokemaking wastewater was conducted between November 14, 1979 and January 17, 1980. During the study, coke production averaged 1,673 metric tons (1,519 tons) per day, while the average wastewater flow was 1,025 m^3/day (0.271 mgd). The corresponding water application rate (liters of water/metric tons of coke produced) during the study was 743 liters/kkg (178 gal./ton). Based on BAT (excluding priority pollutants) limits (1), the allowable pollutant concentrations in the effluent would be:

Parameter	BAT Limit
pH	6.0-9.0
Ammonia, mg/l	13.4
Cyanide-T, mg/l	0.33
Oil and Grease, mg/l	13.4

Parameter	BAT Limit
Phenol, mg/l	0.27
Sulfide, mg/l	0.4
Suspended Solids, mg/l	27
Thiocyanate, mg/l	200

The pilot studies were structured toward meeting the above guidelines.

The advanced waste treatment trains that were investigated on a pilot scale included the following:

1. ACL + FIL + AC
2. ACL + SBD + FIL

Key

AC: activated carbon
ACL: alkaline chlorination
FIL: dual media filtration
SBD: sodium bisulfite dechlorination

In the first pilot treatment train, the wastewater was passed through a two stage alkaline chlorination process for cyanide, phenol, sulfide, thiocyanate and ammonia removal. The wastewater was then filtered for suspended solids removal and dechlorinated on activated carbon. The second treatment train again consisted of alkaline chlorination which was followed by sodium bisulfite dechlorination and dual media filtration.

The results of the pilot program indicated that alkaline chlorination was capable of producing an effluent acceptable for discharge which met the above BAT limitations except for total cyanide. Filtration would be a necessary post-treatment adjunct for meeting suspended solids limitations. If dechlorination of the wastewater were required, activated carbon or sodium bisulfite would be a necessary treatment process. The discussions presented below will evaluate each of these treatment processes from a standpoint of effluent quality, costs and space requirements.

The capital cost information presented in this report has been prepared from a minimum of flow sheet and equipment data. Using the definition found in Perry's "Chemical Engineers' Handbook" (2), this type of estimate would be termed a "study estimate", having an accuracy of ±30 percent.

Wastewater Treatment System

There are four process water streams associated with the by-product coke-making operations at the plant investigated: namely, 1) final cooler wastewater; 2) phenolate wastes, which includes various drips and drains from throughout the by-products plant; 3) light oil separator effluent; and 4) hot oil decanter underflow.

The final cooler wastewater originates from direct spray cooling of the coke oven gas and represents about 31 percent of the total plant flow. The phenolate waste stream (excess flushing liquor) is passed through a free ammonia still, dephenolizer and a fixed ammonia still prior to mixing with other plant wastes. This stream comprises 47 percent of the combined coke plant flow. The hot oil decanter discharge (≈19 percent of plant flow) passes through a dissolved-air flotation unit, containing 4.6 m^2 (50 ft^2) of surface area. The underflow is then blended with other plant effluents. The fourth major process stream, the light oil separator effluent, accounts for approximately three percent of the coke plant effluent flow. The discharges from these four principal coke plant wastewater sources are combined and blended in a 643 m^3(170,000 gal.) equalization tank equipped with mechanical mixers. The equalized effluent is then fed to a full-scale advanced waste treatment system.

Feedwater to the pilot plant system was taken out of the equalization basin during the entire study to approximate a BPT feed stream to the pilot system. The equalized effluent represents a wastewater whose prior treatment closely resembles the EPA model BPT physical/chemical treatment (1). The actual plant pretreatment differs from the BPT model in that only the excess flushing liquor is pretreated in the ammonia stills and dephenolizer rather than the entire combined waste stream. It would be expected that the pollutant parameters for the wastewater would be marginally higher than BPT if the plant pretreatment system were operating properly.

Characteristics of the wastewater obtained from the equalization basin during the study are shown in Table 1.

TABLE 1. COMPARISON OF BPT EFFLUENT LIMITATION GUIDELINES TO ACTUAL PLANT EQUALIZATION BASIN VALUES OBSERVED DURING THE STUDY PERIOD

Parameter	BPT Limit	Analytical value from the research site	
		Average	Range
Cyanide T, mg/l	29	85.2	4.7-267.5
Phenol, mg/l	2	142	68-850
Ammonia, mg/l	123	506	101-2,150
Oil and grease, mg/l	15	54	3-147
Suspended solids, mg/l	49	103	26-361
pH	6.0-9.0		3.8-10.8

As shown in the table, concentrations of pilot plant feedwater were further above the BPT levels than would be expected under normal operation of the existing pretreatment equipment. Equipment problems within the by-product plant led to these unusually high pollutant parameter levels.

Alkaline Chlorination Results

Performance Data--

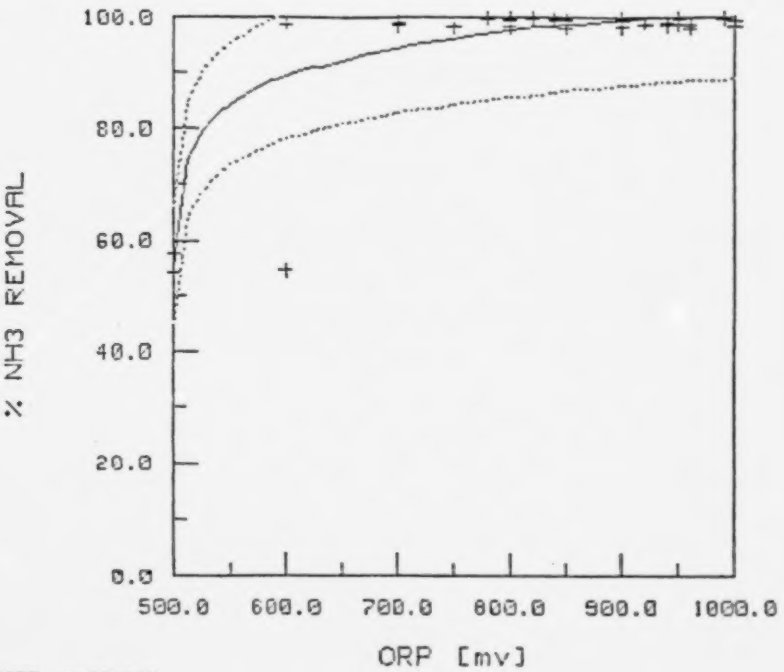
During the study, 40 alkaline chlorination test runs were performed. The pilot test procedure consisted of passing the coke plant wastewater through a series of completely mixed reaction tanks under alkaline and neutral pH conditions in the presence of an oxidizing agent (sodium hypochlorite). In the first reaction tank, sodium hydroxide and sodium hypochlorite were added to the wastewater to oxidize the cyanide present to cyanate. In the second chamber, the wastewater was neutralized in the presence of excess chlorine to oxidize ammonia. The treated wastewater was then filtered and dechlorinated using either activated carbon of sodium metabisulfite. As a by-product of treatment, other parameters exerting a chlorine demand (sulfide, phenol, thiocyanate, etc.) were also oxidized.

The alkaline chlorination system was run continuously over the test period to provide 24 hour composite samples for both conventional and toxic analysis. Feed ammonia concentration ranged from 100 mg/l to a high of almost 2,200 mg/l during the study. However, effluent ammonia was typically less than 10 mg/l. A summary of selected alkaline chlorination test results is shown in Table 2. Figure 4 indicates that effluent ammonia was reduced significantly as the ORP setting was increased. Operating in the 800 to 950 mv range provided sufficient treatment while

TABLE 2. COMPARISON OF SELECTED ALKALINE CHLORINATION RUN EFFLUENTS TO BAT LIMITATIONS

Run No.	ORP mv	NH_3, mg/l	CN_T, mg/l	O&G, mg/l	Phenol, mg/l	$S^=$, mg/l	SS, mg/l	SCN, mg/l
10	900	2	I	-	0.1	<0.2	7	2.3
11	960	2	0.2	-	0.2	<0.2	7	<1
12	960	3	0.7	12	0.4	<0.4	11	2.5
13	950	4	1.2	-	<0.01	<0.2	13	1.5
20	940	3	10.4	3	0.1	<0.2	10	15
22	940	2	6.1	-	0.2	<0.2	6	<1
BAT Limitations		13.4	0.33	13.4	0.27	0.4	27	200

I: Interference



INTERCEPT = 35.103
SLOPE = 17.117
Rsquared = .719
CORRELATION= .848

Figure 4. Ammonia removal versus ORP (mv) - alkaline chlorination.

maintaining the lowest possible chlorine residual. The data presented in Table 32 indicate that alkaline chlorination was effective in reducing pollutant concentrations to below BAT levels with the exception of total cyanide. Obviously, the presence of complexing agents in the coke plant effluent prevented complete oxidation of the cyanide by chlorine.

Based on the alkaline chlorination pilot results, a full scale treatment system could be expected to routinely meet its NPDES permit limitations for all parameters except total cyanide. However, it should be remembered that the average influent cyanide-T value of the wastewater tested was approximately three times the BPT limit (30 mg/l) and cyanide-T values as high as nine times the BPT valve were observed. It is unknown if BAT cyanide-T levels could be consistently met if better pre-treatment were provided. Values of cyanide-A exiting the pilot treatment system were typically <0.05 mg/l.

Cost Data

Listed in Tables 3 and 4 are the costs associated with treatment of the coke plant wastewater. Cost estimates have been presented for design flows of 379 m^3/day (0.1 mgd), 1,022 m^3/day (0.27 mgd) and 3,785 m^3/day (1.0 mgd). Cost data were developed for treatment of the coke plant wastewater as received (Table 3 - Run no. 10 was assumed typical) and for an assumed BPT coke plant wastewater feed (Table 4).

TABLE 3. ALKALINE CHLORINATION COST SUMMARY - COSTING BASED ON COKE PLANT FEEDWATER OBSERVED DURING STUDY

Size, m^3/day (mgd)	379 (0.1)	1,022 (0.27)	3,785 (1.0)
Capital costs, ($)[a]	533,000	711,000	1,588,000
Annualized costs, ($/yr)[a,b]	678,000	1,656,000	5,947,000
Annualized costs, $/3,785 liters ($/1,000 gal.)[a,b]	19.94	17.47	16.70
Land requirement, m^2 (acres)	139 (0.034)	223 (0.055)	465 (0.115)

a. All prices effective as of May, 1980.
b. Annualized Cost = Operating Cost + Capital Amortization (20 yr life; 7.125%).

Comparing the cost data in Tables 3 and 4, it is evident that cost savings of approximately 45 percent would result if the proposed BAT system were applied to a waste stream that met BPT pollutant parameters. For example, assuming current wastewater pollutant concentrations, estimated treatment cost of $17.47/3,785 liters ($17.47/1,000 gal.) would be realized for a 1,022 m^3/day (0.27 mgd) wastewater treatment facility.

TABLE 4. ALKALINE CHLORINATION COST SUMMARY - BPT FEEDWATER ASSUMED

Size, m^3/day (mgd)	379 (0.1)	1,022 (0.27)	3,785 (1.0)
Capital costs, (\$)[a]	501,000	681,000	1,217,000
Annualized costs, (\$/yr)[a,b]	379,000	848,000	3,174,000
Annualized costs, \$/3,785 liters (\$/1,000 gal.)[a,b]	11.70	9.26	9.01
Land requirement, m^2 (acres)	139 (0.034)	2.23 (0.055)	465 (0.115)

a. All prices are effective as of May, 1980.

b. Annualized Costs = Operating Cost + Capital Amortization (20 yr life; 7.125%).

With a BPT influent stream, this cost could be reduced to \$9.26/3,785 liters (\$9.21/1,000 gal.). Both systems were designed for a 30 minute detention time in the cyanide oxidation tank followed by a 6 minute reaction tank for ammonia removal. The use of chlorine gas was also assumed.

Land requirements for both designs would be about the same.

Dual Media Filtration Results

Performance Data--

Dual media filtration tests were performed on the coke plant effluent as a polishing step from November, 1979 to January, 1980. Tests were conducted both with and without polymer.

Filtration results of the effluent without polymer are summarized in Table 5. Filtration removed significant quantities of suspended solids (78 percent removal). Table 5 also shows the average, maximum and minimum influent and effluent characteristics when chemically pretreated coke plant effluent was filtered with polymer as a coagulant aid. Overall removal of suspended solids (96 percent removal) was greatly improved with addition of the cationic polymer at a dosage of 3 mg/l.

TABLE 5. DUAL MEDIA FILTRATION PILOT STUDY RESULTS

	Suspended solids, mg/l No polymer		Suspended solids, mg/l Polymer added	
	Inf.	Eff.	Inf.	Eff.
Average	51	11	71	3
Maximum	139	36	152	9
Minimum	7	2	10	1

Both filtered effluents easily met BAT limits for suspended solids.

Cost Data--
A summary of the costs associated with dual media filtration of the alkaline chlorinated coke plant wastewater is shown in Tables 6 and 7. Table 6 is costed assuming no polymer addition, while Table 7 includes a polymer addition system at an assumed dose of 3 mg/l. Both designs were prepared for a filtration rate of 163 l/min/m^2 (4 gpm/ft^2). Cost estimates were prepared for flows of 379 m^3/day (0.1 mgd), 1,022 m^3/day (0.27 mgd) and 3,785 m^3/day (1.0 mgd).

TABLE 6. DUAL MEDIA FILTER COST SUMMARY - NO POLYMER ADDITION

Design flow, m^3/day (mgd)	379 (0.1)	1,022 (0.27)	3,785 (1.0)
Capital cost, ($)[a]	129,000	218,000	455,000
Annualized cost, ($/yr)[a,b]	35,000	47,000	83,000
Annualized cost $/3,785 liters ($/1,000 gal.)[a,b]	0.96	0.48	0.23
Land requirement, m^2 (acres)	70 (0.017)	90 (0.022)	130 (0.032)

a. All prices effective as of May, 1980.
b. Annualized Costs = Operating Cost + Capital Amortization (20 yr life; 7.125%).

TABLE 7. DUAL MEDIA FILTER COST SUMMARY - POLYMER ADDITION

Design flow, m^3/day (mgd)	379 (0.1)	1,022 (0.27)	3,785 (1.0)
Capital cost, ($)[a]	153,000	243,000	486,000
Annualized cost, ($/yr)[a,b]	41,000	57,000	113,000
Annualized cost $/3,785 liters ($/1,000 gal.)[a,b]	1.12	0.58	0.31
Land requirement, m^2 (acres)	80 (0.02)	100 (0.024)	140 (0.034)

a. All prices effective as of May, 1980.
b. Annualized Costs = Operating Cost + Capital Amortization (20 yr life; 7.125%).

Comparison of Tables 6 and 7 indicates that a polymer addition system adds about $25,000 to the capital cost of a 1,022 m^3/day (0.27 mgd) design. Similarly, operating costs are increased by $0.10/3,785 liters ($0.10/1,000 gal.) when polymer is added. Since both treatment systems would be expected to meet BAT suspended solids limits, polymer addition is not recommended.

Land requirements are also presented in Tables 6 and 7. For a 1,022 m^3/day (0.27 mgd) design, an area of approximately 90 m^2 (0.022 acres) would be required.

Activated Carbon Results

Performance Data--

The use of activated carbon was investigated to determine its effectiveness as (1) a dechlorinating agent and (2) in the removal of priority pollutants. In this dechlorination process, the carbon will convert the excess chlorine produced by the alkaline chlorination process into chlorides and other harmless by-products.

The average influent chlorine concentration to the carbon system during the study was 63.6 mg/l. The average chlorine removal rate across the carbon bed was 95 percent with a range from 83.9 to 100 percent. Removal efficiency decreased as volume processed increased. The carbon was also effective in reducing influent cyanide-T by 42 percent and TOC by 61 percent. Effluent phenol concentration from the carbon was decreased by 73 percent.

Cost Data--

The vendor prepared cost data for the activated carbon are shown in Table 8. Cost estimates are listed for flows of 379 m^3/day (0.1 mgd), 1,022 m^3/day (0.27 mgd) and 3,785 m^3/day (1.0 mgd). For full scale design purposes, a contact time of 29 minutes and an impurity loading of 0.1 g Cl_2/g carbon were chosen. The full scale system would have the adsorbers operated in parallel at an approximate flow rate of 106 l/min/m^2 (2.6 gpm/ft^2).

TABLE 8. ACTIVATED CARBON DECHLORINATION COST SUMMARY

Design flow, m^3/day (mgd)	379 (0.1)	1,022 (0.27)	3,785 (1.0)
Capital cost, (\$)[a]	601,000	1,122,000	2,477,000
Annualized cost, (\$/yr)[a,b]	228,000	539,000	1,781,000
Annualized cost, \$/3,785 liters (\$/1,000 gal.)[a,b]	6.24	5.47	4.88
Land requirement, m^2 (acres)	106 (0.026)	177 (0.043)	367 (0.090)

a. All prices effective as of May, 1980.

b. Annualized Costs = Operating Cost + Capital Amortization (20 yr life; 7.125%).

The capital cost for a 1,022 m^3/day (0.27 mgd) system would be \$1,122,000. The annualized cost is estimated at \$5.47/3,785 liters (\$5.47/1,000 gal.). Space requirements for this design are estimated at 177 m^2 (0.043 acres). Pretreatment of the wastewater by filtration would be required for removal of suspended solids, however, this cost has not been included in the Table 8 cost data.

Sodium Bisulfite Dechlorination Results

Performance Data--

Sodium bisulfite was investigated as a dechlorinating agent during the pilot study. The results of the pilot study determined that 100 percent of the chlorine could be removed at a bisulfite:chlorine ratio of 2:1. During the study, chlorine removal was found to be a function of bisulfite to chlorine ratio. The studies were performed at a wastewater detention time of 30 minutes under complete mixing conditions.

Cost Data--

The costs for treatment of the coke plant wastewater by sodium bisulfite are summarized in Table 9. The design influent chlorine concentration was assumed to be 174 mg/l while the design effluent was <1 mg/l. A chlorine to sodium bisulfite ratio of 2:1 and a contact time of 30 minutes was used for design.

TABLE 9. SODIUM BISULFITE DECHLORINATION COST SUMMARY

Design flow, m^3/day (mgd)	379 (0.1)	1,022 (0.27)	3,785 (1.0)
Capital cost, ($)[a]	117,000	174,000	255,000
Annualized cost, ($/yr)[a,b]	54,000	97,000	262,000
Annualized cost, $/3,785 liters ($/1,000 gal.)[a,b]	1.48	0.98	0.72
Land requirement, m^2 (acres)	35 (0.009)	60 (0.015)	110 (0.027)

a. All prices effective as of May, 1980.

b. Annualized Cost = Operating Cost + Capital Amortization (20 yr life; 7.125%).

A 1,022 m^3/day (0.27 mgd) full scale plant would have a capital cost of $174,000 with an annualized cost of about $0.98/3,785 liters ($0.98/1,000 gal.). Space requirements for this system design were estimated at 60 m^2 (0.015 acres).

If the influent chlorine concentration were reduced to 63.6 mg/l (which is comparable to the activated carbon design) the annualized cost shown in Table 9 could be reduced by about 50 percent. There would be no capital cost savings realized. Estimated annualized costs for this system are shown in the following list.

Flow	Total Annualized Cost
378.5 m^3/day (0.1 mgd)	$41,000/yr $1.12/3,785 liters ($1.12/1,000 gal.)
1,022 m^3/day (0.27 mgd)	$62,000/yr $0.63/3,785 liters ($0.63/1,000 gal.)
3,785 m^3/day (1.0 mgd)	$133,000/yr $0.36/3,785 liters ($0.36/1,000 gal.)

Priority Pollutant Discussion

Priority pollutant analyses were performed on 63 samples of the coke plant wastewater plus blanks during the Phase I (alkaline chlorination-filtration-activated carbon) and Phase II (alkaline chlorination-sodium bisulfite dechlorination-filtration) investigations.

Volatile Organics--

Chlorination of the influent resulted in decreasing the concentration of benzene, acrylonitrile and toluene by approximately half. Chlorination increased chloroform concentrations from the 8 to 170 μg/l found in the raw influent to 3,700 to 22,000 μg/l in the chlorinated effluent. Dibromochloromethane, carbon tetrachloride, 1, 2 dichloroethane, chlorobenzene and bromoform were not detected in the influent samples; however, significant concentrations were found in the chlorinated effluent. Neither Phase 1 or Phase 2 treatment systems were completely effective in the removal of volatile organic priority pollutants. However, Phase 1 processes were superior, removing 10 to 100 times more volatile organics than Phase 2. Only negligible volatile organics removals were observed during Phase 2.

Semivolatile Organics--

Phase 1 provided a more complete semivolatile organic priority pollutant removal than Phase 2. The Phase 1 operation removed all semivolatile organic priority pollutants to low levels; Phase 2 also reduced all semivolatile organics to low levels except for naphthalene.

Metals--

Phase 1 final effluent metals concentrations were very close to the initial raw influent levels. Similarly, priority pollutant metals were not removed in the Phase 2 operation.

DISCUSSION

The pilot program determined that a treatment train consisting of alkaline chlorination and filtration was effective in producing a coke plant wastewater that would meet the effluent requirements for all BAT parameters (non-priority pollutant) with the possible exception of total cyanide. However, chlorination increases the concentrations of some toxic compounds;

in other cases, chlorination is responsible for the production of toxics not originally observed in the feedwater. Activated carbon and sodium bisulfite were capable of reducing residual chlorine concentrations from the alkaline chlorinated wastewater; however, neither of these treatment processes would be necessary to meet conventional BAT requirements, unless a chlorine discharge limit were imposed on the coke plant. Activated carbon was, however, effective in the removal of priority pollutants.

Cost summaries are presented in Tables 10 and 11 for each of the two treatment trains investigated in this pilot study. The costs shown for alkaline chlorination were for treatment of the wastewater at concentrations observed during the pilot study.

Alkaline chlorination and filtration capital costs were estimated at \$929,000 for a 1,022 m^3/day (0.27 mgd) design. The corresponding annualized costs would be \$17.95/3,785 liters (\$17.95/1,000 gal.). If activated carbon were added for dechlorination, as shown in Table 10, this would increase the capital investment by \$1,122,000 and the annualized cost by \$5.47/3,785 liters (\$5.47/1,000 gal.). An alternate, more economical dechlorination technique would involve treatment by sodium bisulfite. The capital cost for a 1,022 m^3/day (0.27 mgd) sodium bisulfite dechlorination system would be \$174,000 and have an estimated annualized cost of \$0.98/3,785 liters (\$0.98/1,000 gal.). This is illustrated in Table 11.

If the proposed system were applied to a stream that met BPT pollutant parameters, alkaline chlorination annualized costs could be reduced by \$8.21/3,785 liters (\$8.21/1,000 gal.) for a 1,022 m^3/day (0.27 mgd) system. A capital cost reduction of \$30,000 would also be realized. Reduction of the impurity levels of the coke plant wastewater would appear to be the most logical, economical first step toward meeting the 1984 guidelines. Another important economic consideration is the widely fluctuating interest rate that has been observed in this country over the past several months. A significant increase in the amortization rate would have a dramatic effect on the annualized cost of some treatment train components. For example, if the amortization rate were increased to say, 12 percent, the annualized costs realized for each treatment train technology would increase substantially as shown on the following page.

It is evident from the above table that the higher interest rate more seriously affects the highly capital cost intensive technologies. For example, assuming a 12 percent amortization rate, the total annualized cost for a 1,022 m^3/day (0.27 mgd) dual media filtration system (which is capital cost intensive) increased by 17 percent, compared to an increase of only 1.6 percent for a similar sized alkaline chlorination system (which is operating cost intensive because of high chemical usage). Thus it can be seen that the interest rate must also be carefully evaluated as a part of any coke plant's equipment planning to meet BAT guidelines.

ALKALINE CHLORINATION - FILTRATION - ACTIVATED CARBON

Design Flow, m^3/day (mgd)	379 (0.1)	1,022 (0.27)	3,785 (1.0)	379 (0.1)	1,022 (0.27)	3,785 (1.0)
	Capital amortization (20 yr life)			Total annualized cost, \$/3,785 ℓ (\$/1,000 gal)		
Alkaline chlorination						
@ 7.125%	50,000	66,000	148,000	19.94	17.47	16.70
@ 12.0%	71,000	95,000	213,000	20.50	17.76	16.88
Filtration						
@ 7.125%	12,000	21,000	44,000	0.96	0.48	0.23
@ 12.0%	17,000	29,000	61,000	1.10	0.56	0.27
Activated carbon						
@ 7.125%	57,000	107,000	236,000	6.24	5.47	4.88
@ 12.0%	80,000	150,000	332,000	6.88	5.91	5.14
Sodium bisulfite						
@ 7.125%	11,000	17,000	24,000	1.48	0.98	0.72
@ 12.0%	16,000	23,000	34,000	1.62	1.05	0.76

TABLE 10. ALKALINE CHLORINATION - FILTRATION -ACTIVATED CARBON TREATMENT TRAIN COST SUMMARY

Design flow, m^3/day (mgd)	379 (0.1)	1,022 (0.27)	3,785 (1.0)
Capital costs ($)[a]			
Alkaline chlorination	533,000	711,000	1,588,000
Filtration	129,000	218,000	455,000
Total	662,000	929,000	2,043,000
With activated carbon	601,000	1,122,000	2,477,000
Total	1,263,000	2,151,000	4,520,000
Annualized costs ($/yr)[a,b]			
Alkaline chlorination	678,000	1,656,000	5,947,000
Filtration	35,000	47,000	83,000
Total	713,000	1,703,000	6,030,000
With activated carbon	228,000	539,000	1,781,000
Total	941,000	2,342,000	7,811,000
Annualized costs $/3,785 liters ($/1,000 gal.)[a,b]			
Alkaline chlorination	19.94	17.47	16.70
Filtration	0.96	0.48	0.23
Total	20.90	17.95	16.93
With activated carbon	6.24	5.47	4.88
Total	27.14	23.42	21.81
Land requirements m^2 (acres)			
Alkaline chlorination	139 (0.034)	223 (0.055)	465 (0.115)
Filtration	70 (0.017)	90 (0.022)	130 (0.032)
Total	209 (0.051)	313 (0.077)	595 (0.147)
With activated carbon	106 (0.026)	177 (0.043)	367 (0.090)
Total	315 (0.077)	490 (0.120)	962 (0.237)

a. All prices are effective as of May, 1980.

b. Annualized Costs = Operating Costs (Electrical, Operators, Maintenance, etc.) + Capital Amortization (20 yr life, 7.125%).

TABLE 11. ALKALINE CHLORINATION - SODIUM BISULFITE - FILTRATION TREATMENT TRAIN COST SUMMARY

Design flow, m^3/day (mgd)	379 (0.1)	1,022 (0.27)	3,785 (1.0)
Capital costs ($)[a]			
Alkaline chlorination	533,000	711,000	1,588,000
Filtration	129,000	218,000	455,000
Total	662,000	929,000	2,043,000
With sodium bisulfite	117,000	174,000	255,000
Total	779,000	1,103,000	2,298,000
Annualized costs ($/yr)[a,b]			
Alkaline chlorination	678,000	1,656,000	5,947,000
Filtration	35,000	47,000	83,000
Total	713,000	1,703,000	6,030,000
With sodium bisulfite	54,000	97,000	262,000
Total	767,000	1,800,000	6,292,000
Annualized costs $/3,785 liters ($/1,000 gal.)[a,b]			
Alkaline chlorination	19.94	17.47	16.70
Filtration	0.96	0.48	0.23
Total	20.90	17.95	16.93
With sodium bisulfite	1.48	0.98	0.72
Total	22.38	18.93	17.65
Land requirements m^2 (acres)			
Alkaline chlorination	139 (0.034)	223 (0.055)	465 (0.115)
Filtration	70 (0.017)	90 (0.022)	130 (0.032)
Total	209 (0.051)	313 (0.077)	595 (0.147)
With sodium bisulfite	35 (0.009)	60 (0.015)	110 (0.027)
Total	244 (0.060)	373 (0.092)	705 (0.174)

a. All prices are effective as of May, 1980.

b. Annualized Costs = Operating Costs (Electrical, Operators, Maintenance, etc.) + Capital Amortization (20 yr life, 7.125%).

SECTION 3

DESCRIPTION OF THE RESEARCH SITE INVESTIGATED

BY-PRODUCT COKE PLANT

General

The by-product cokemaking plant chosen for the study was located on the Ohio River in western Pennsylvania. Coke production during the pilot study averaged 1,673 metric tons (1,519 tons) per day, while the average wastewater flow was 1,025 m^3/day (0.271 mgd). The corresponding average water application rate (liters of water/metric ton of coke produced) during the study was 743 liters/kkg (178 gal./ton). Shown in Figure 5 is a photograph of the field setup at the coke plant. Production figures are shown in Appendix A.

Wastewater Treatment System

There are four process water streams associated with the by-product cokemaking operations at the plant investigated; namely (1) final cooler wastewater; (2) the phenolate waste stream, which includes drips and drains from the by-products portion of the plant and the ammonium sulfate production area; (3) light oil separator effluent; and (4) hot oil decanter underflow. Samples of these streams were collected over a 3 consecutive day period. The analytical results are shown in Table 12. The data indicate that the final cooler wastewater stream contained significant concentrations of phenol, ammonia, sulfide and cyanide. Almost all of the cyanide present was amenable to chlorination. The hot oil decanter contained moderate concentrations of phenol and oil and grease. Only negligible amounts of ammonia and cyanide were present. The phenolate waste stream was highest in thiocyanate (753 mg/l ave.) and also contained significant concentrations of sulfide. The light oil separator contained concentrations of phenol (125 mg/l ave.), total cyanide (175 mg/l ave.) and sulfide (138 mg/l ave.). Approximately 98 percent of the cyanide present was amenable to chlorination.

The final cooler wastewater originates from direct spray cooling of the coke oven gas and represents about 31 percent of the total plant flow. The phenolate waste stream (excess flushing liquor) is passed through a free ammonia still, dephenolizer and a fixed ammonia still prior to discharge. This stream comprises 47 percent of the combined coke plant flow. The hot oil decanter discharge (~19% of plant flow) passes through a dissolved-air flotation unit, containing 4.6 m^2 (50 ft^2) of surface area. The underflow is then blended with other plant effluents. The fourth major process stream,

Figure 5. Field set-up - by-product cokemaking physical/chemical test site.

the light oil separator effluent accounts for approximately three percent of the coke plant effluent flow. The discharges from these four principal coke plant wastewater sources are combined and blended in a 643 m^3 (170,000 gal.) equalization tank equipped with mechanical mixers. The equalized effluent, which approximates a Best Practicable Control Technology (BPT) Currently Available wastewater, is then fed to a full-scale advanced waste treatment system designed to meet future Best Available Technology (BAT) Economically Achievable guidelines.

The first advanced waste treatment system used by the plant is clarification.

Equalized wastewater is fed in parallel to two clarifiers, each 10.7 meters (35 ft) in diameter with a 4.4 m (14.5 ft) sidewall. The clarifier underflow is sent to a vacuum filter for sludge dewatering. The clarified overflow is pumped to two parallel mixed media filters, each 3 m (10 ft) in diameter. The filtration system is designed for a loading of 228 liters/min/m^2 (5.6 gpm/ft^2). Filtered effluent is then passed downflow through a series of two activated carbon columns for soluble organics removal. Each column is 3.05 m (10 ft) in diameter and is designed for a 5.8 m (19 ft) carbon bed depth. The treated wastewater is then discharged to the Ohio River. During the study, the host plant was in the process of getting a cyanide oxidation system on-line. This unit will utilize sodium hydroxide and chlorine to provide post-treatment to the activated carbon effluent. A schematic of the coke plant's wastewater treatment system is shown in Figure 6.

TABLE 12. RESULTS OF PLANT WASTE STREAM SAMPLE ANALYSIS

ERC No.	Date	Time	Source	SS, mg/l	Phenol, mg/l	NH_3, mg/l	Sulfide, mg/l	CN_T, mg/l	CN_A, mg/l	SCN, mg/l	O&G, mg/l	pH
9140	1/14/80	0838	Final Cooler	1	200	86	72	355.6	355.4	49	22	7.3
9159	1/15/80	0903	Final Cooler	1	230	96	66.4	308.3	307.2	63	5	7.2
9163	1/16/80	0858	Final Cooler	2	230	351	325	452.5	448.4	120	12	8.2
9141	1/14/80	0843	Hot Oil Decater	14	80	7	<0.4	0.44	<0.05	13	30	7.2
9157	1/15/80	0855	Hot Oil Decater	98	34	7	2.1	0.39	<0.05	13.6	439	6.4
9161	1/16/80	0845	Hot Oil Decater	36	44	9	2.1	0.33	<0.05	16	243	7.1
9142	1/14/80	0855	Phenolate Waste	92	8.0	69	117	3.14	<0.05	860	61	12.4
9160	1/15/80	0910	Phenolate Waste	25	42	35	103	3.54	3.3	700	267	12.2
9162	1/16/80	0852	Phenolate Waste	52	36	24	101	3.94	0.34	700	16	12.0
9143	1/14/80	0903	Light Oil Separator	7	140	30	62.5	22.0	21.61	6.2	3	6.4
9158	1/15/80	0858	Light Oil Separator	3	134	35	118	177.5	174.7	11	4	5.7
9164	1/16/80	1055	Light Oil Separator	2	102	102	233	325.0	318.5	16	8	6.3

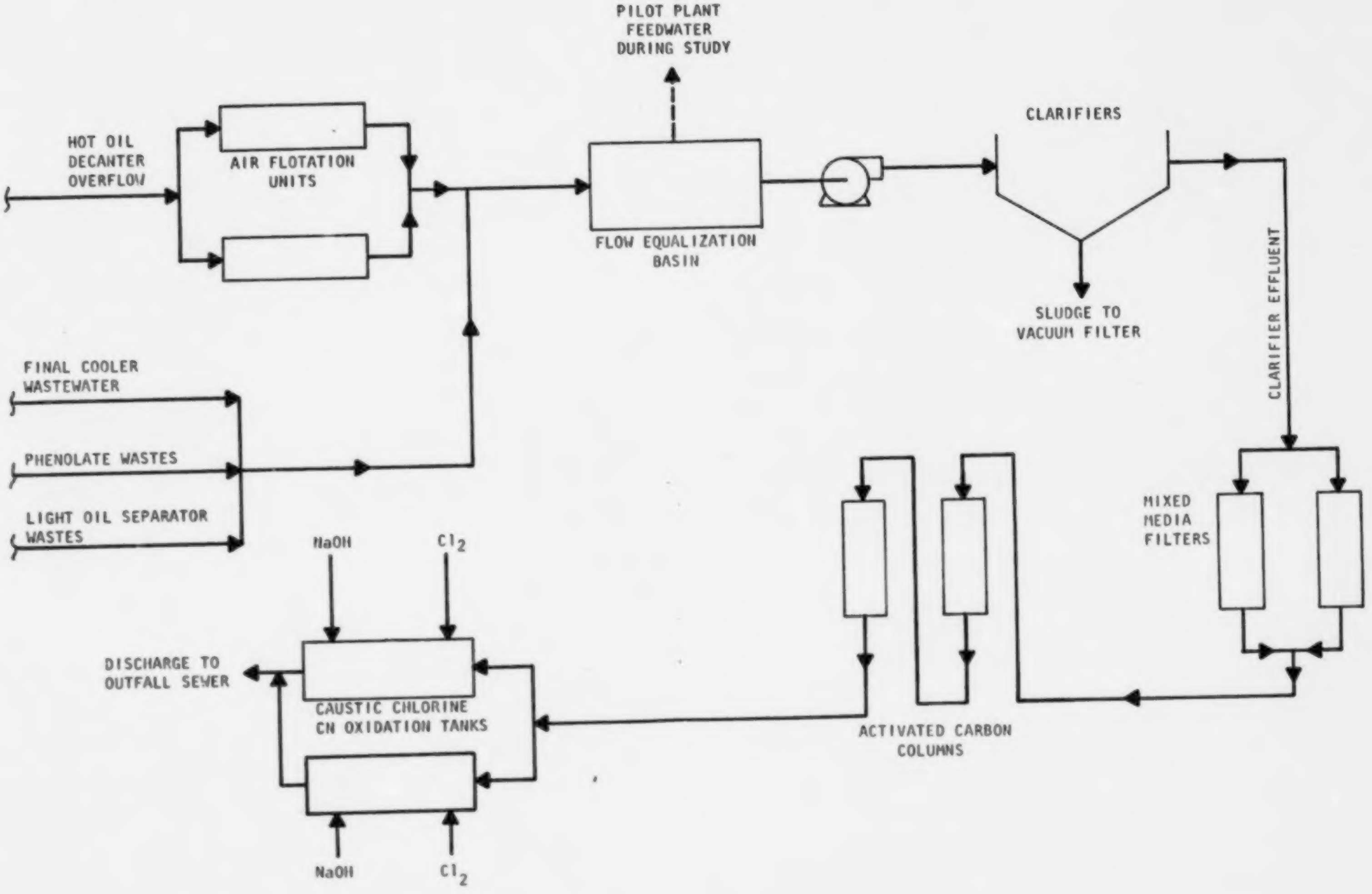

PILOT PLANT
FEEDWATER
DURING STUDY
HOT OIL
DECANTER
OVERFLOW
AIR FLOTATION
UNITS
FLOW EQUALIZATION
BASIN
CLARIFIERS
SLUDGE TO
VACUUM FILTER
CLARIFIER EFFLUENT
FINAL COOLER
WASTEWATER
PHENOLATE WASTES
LIGHT OIL SEPARATOR
WASTES
MIXED
MEDIA
FILTERS
NaOH
Cl_2
DISCHARGE TO
OUTFALL SEWER
CAUSTIC CHLORINE
CN OXIDATION TANKS
ACTIVATED CARBON
COLUMNS
NaOH
Cl_2

Figure 6. Research site wastewater treatment system.

Feedwater to the pilot plant system was taken out of the equalization basin during the entire study to approximate a BPT feed stream to the pilot stream. The equalized effluent represents a wastewater whose prior treatment closely resembles the EPA model BPT physical/chemical treatment (1). The actual plant pretreatment differs from the BPT model in that only the excess flushing liquor is pretreated in the ammonia stills and dephenolizer rather than the entire combined waste stream. It would be expected that the pollutant parameters for the wastewater would be marginally higher than BPT if the plant pretreatment system were operating properly.

Best Practicable Control Technology Currently Available and Best Available Technology Economically Achievable limitation guidelines for the physical-chemical treatment of the by-product cokemaking subcategory are shown in the following table. The limitations were taken from the October, 1979 Development Document for Proposed Effluent Limitations Guidelines and Standards for the Iron and Steel Manufacturing Point Source Category - By-product Cokemaking Subcategory (1).

Effluent Characteristic	BPT Limitations kg/kkg lb/1000 lb	BAT Limitations[a,b] kg/kkg lb/1000 lb
Cyanide_T	0.0219	0.000227
Phenol	0.015	0.000182
Ammonia	0.0912	0.00909
Oil & Grease	0.0109	0.00909
Suspended Solids	0.0365	0.0182
Sulfide	-	0.000273
Thiocyanate	-	0.136
pH	6.0-9.0	6.0-9.0

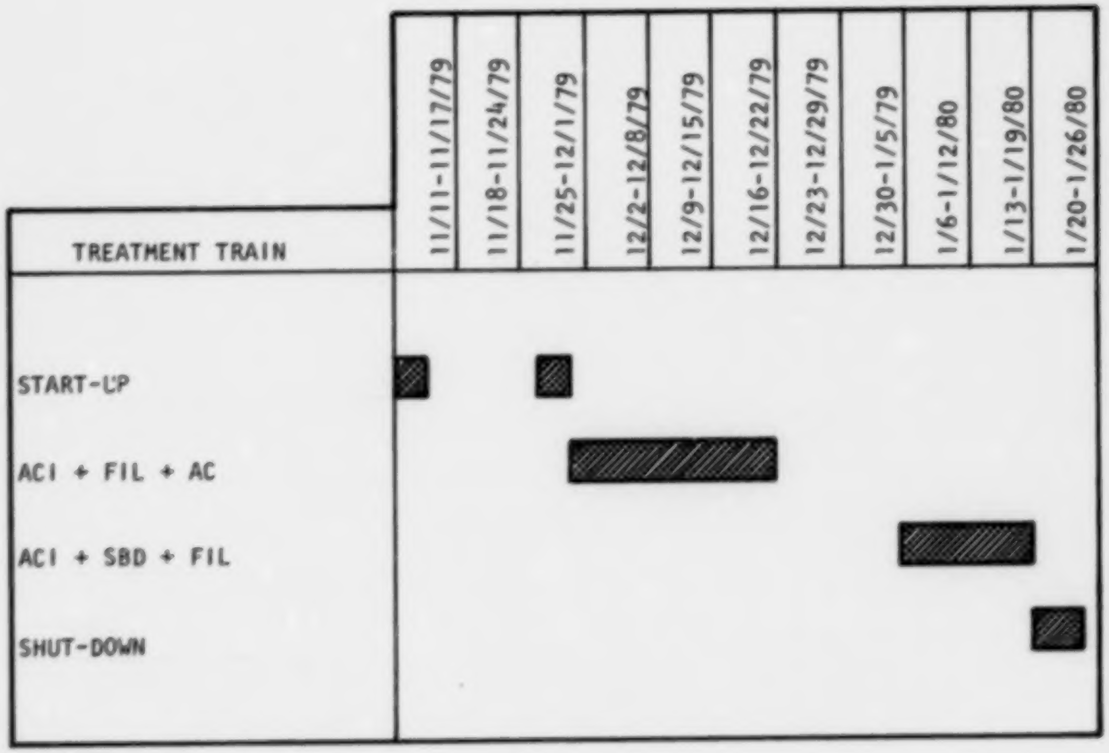
a. Based on proposed limitations for Alternative 2 - By-product cokemaking - Physical/Chemical Treatment Systems

b. Limitations are also proposed for selected toxic pollutants

As shown above, proposed effluent limitations are based on kilograms (pounds) of pollutant discharged per 1,000 kg (1,000 lb) of coke produced.

Duration of the Study

The period of time spent on site was approximately 10 weeks, including time for startup, treatment train switch over, and shutdown of the vans. The mobile units arrived at the research site on November 14, 1979. Actual testing began on November 28, 1979 and continued until January 17, 1980. The pilot system was shut down from November 17-26, 1979 and December 21, 1979 until January 2, 1980 for the holidays. A field testing schedule is shown in Figure 7.



KEY

AC = activated carbon
ACI = alkaline chlorination
FIL = dual media filtration
SBD = sodium bisulfite dechlorination

Figure 7. Field testing schedule by-product cokemaking-physical chemical test site.

SECTION 4

BENCH SCALE TESTING

SUMMARY

Bench scale treatment tests were performed by the Environmental Research Center of Rexnord on a sample of equalized effluent from a coke by-product plant. All bench scale tests were performed between October 24 and November 7, 1979. The purpose of these tests was to investigate treatment feasibility, obtain basic design data for the pilot plant and generate information required to plan pilot plant tests. The bench scale tests were structured to meet Best Available Technology (BAT) Economically Achievable limitations.

Processes investigated included alkaline chlorination, dual media filtration, activated carbon dechlorination and sodium bisulfite dechlorination. Test results indicated that the above treatment trains were promising methods for removal of substantial amounts of objectionable contaminants to meet BAT (non-priority pollutants) limitations.

CONCLUSIONS AND RECOMMENDATIONS

1. Bench scale testing was performed to investigate the effectiveness of various advanced treatment methods for meeting BAT effluent requirements. It was concluded that alkaline chlorination, filtration and dechlorination (by activated carbon or sodium bisulfite addition) were effective in removing substantial amounts of objectionable BAT limiting contaminants.

2. Alkaline Chlorination - In order to remove excess solids and residual chlorine, alkaline chlorination should be followed by filtration and dechlorination.

    a. Ammonia concentration of the wastewater was reduced to less than 10 mg/l when a chlorine dose 1.5 times the theoretical amount needed (8.7 mg Cl_2/mg NH_3N) was used. Cyanide-T was also reduced but not to the desired level (0.33 mg/l).
    b. Treatment of chlorinated wastewater with activated carbon resulted in reduction of residual chlorine, cyanide-T and TOC.
    c. The use of sodium bisulfite facilitated the removal of residual chlorine.

3. Dual media filtration - Direct filtration through sand and anthracite media was effective in removing suspended solids and reducing effluent turbidity.

4. Activated Carbon Adsorption - In order to remove residual chlorine and reduce cyanide and phenol levels in chlorinated wastewater, activated carbon adsorption should follow alkaline chlorination and dual media filtration. Carbon isotherm tests indicated that 0.10 mg chlorine would be adsorbed per gram of carbon in reducing the effluent chlorine to less than 1.0 mg/l.

5. Sodium bisulfite dechlorination - Sodium bisulfite effectively removed residual chlorine when applied at a rate of 1.8 mg bisulfite per 1.0 mg of chlorine.

A detailed discussion of bench scale findings can be found in Appendix B-1.

SECTION 5

TREATMENT TECHNOLOGIES INVESTIGATED

INTRODUCTION

This section describes the treatment technologies studied in this pilot scale program at the by-product coke plant research site. For each technology investigated (alkaline chlorination, dual media filtration, sodium bisulfite dechlorination, activated carbon) a general section has been provided for the process introduction, the description of the pilot equipment, and the experimental program performed. A separate discussion on the sampling and analytical procedures used in the study is presented below.

SAMPLING AND ANALYTICAL PROCEDURES

Samples taken during the experimental study included grabs and 24 hour composites. The sampling procedure and data collection points for each of the treatment processes is shown in Table 13.

The major analytical parameters tested for during the study are presented in Table 14. It should be noted that all indicated parameters were not run on all samples. Typically, raw waste was sampled daily throughout the study period. Various product and by-product streams of the different treatment trains were sampled over selected periods. A more detailed description of the sampling and analytical schedule for each process is presented in Section 6.

Pertinent preservation methods in accordance with EPA (3) were performed in the field immediately after collection. A unique data sheet accompanied each shipment of samples to the Rexnord Environmental Research Center Laboratory. This also provided a chain-of-custody record.

ALKALINE CHLORINATION

Introduction

Alkaline chlorination is an effective treatment process for reducing influent concentrations of cyanide and ammonia. Destruction of cyanide by chlorine oxidation occurs according to the following reaction:

$$2NaCN + 5NaOCl + H_2O \longrightarrow N_2 + 2NaHCO_3 + 5NaCl$$

TABLE 13. SAMPLING PROCEDURE AND DATA COLLECTION POINTS

	Sampling point/sample type				
	Influent composite	Effluent composite	Influent grab	Effluent grab	Specific grab
Raw waste	x		x		
Alk. chlor.	x		x	x	x
Multi-media filtration	x	x			x
backwash					x
Sodium bisulfite dechlorination	x	x			x
Activated carbon	x	x	x	x	
col. #1					x
col. #2					x
col. #3					x
col. #4					x

Note: (x) indicates sampling point.

TABLE 14. PERTINENT ANALYTICAL PARAMETERS

Analysis	Raw waste	Cyanide treatment	Ammonia treatment	Multi-media		Act. carbon		Sodium bisulfite
				effluent	backwash	Effluent	Profiles	Effluent
pH	x	x	x	x		x	x	x
Suspended solids	x	x	x	x	x	x		x
Turbidity	x			x		x		
Oil & Grease	x			x		x		
TOC	x			x		x		
BOD	x			x		x		
Cyanide	x	x	x	x		x		
Phenol	x			x		x		
Color	x			x		x		
Sulfide	x			x		x		
Total dissolved solids	x			x		x		
TKN	x		x					
NH_3	x	x	x	x		x		x
NO_3-N	x	x	x	x		x		x
Chloride	x			x		x		x
Cl_2 residual	x	x	x	x		x	x	x

Notes: 1) All indicated parameters were not run on all samples.

The cyanide is first converted into cyanate at an elevated pH. Chlorine oxidation continues in the second step (neutral pH) with cyanate being oxidized to nitrogen and carbon dioxide, the latter reacting with the alkalinity in the water to form bicarbonates, provided sufficient reaction time is available.

Ammonia nitrogen is also converted to nitrogen gas and end products at neutral pH by breakpoint chlorination. The overall reaction may be expressed by the equation shown below:

$$NH_4^+ + HOCl \longrightarrow NH_2Cl + H_2O + H^+$$

$$2NH_2Cl + HOCl \longrightarrow N_2\uparrow + 3HCl + H_2O$$

Description of the Pilot Equipment

The pilot alkaline chlorination system consisted of the reaction tanks, stock tanks, pH and oxidation-reduction potential (ORP) meters, chemical pumps, control panel, etc. necessary to operate the units. The system is designed to treat influent wastewater flows up to 45.4 liters/min (12 gpm) and consists of four cells:

Cell No. 1 -	1,362.6 liters	(360 gal.)	[Bypassed during study]
Cell No. 2 -	227 liters	(60 gal.)	[Bypassed during study]
Cell No. 3 -	227 liters	(60 gal.)	
Cell No. 4 -	45.4 liters	(12 gal.)	

A schematic of a typical system set-up is shown in Figure 8.

Experimental Program

The objectives of the pilot alkaline chlorination tests were to obtain sufficient information for full-scale design. Of vital interest were performance characteristics for determining effluent quality and design parameters to insure the most cost effective equipment size.

Performance characteristics include effluent quality and the consistency of effluent during varying feed conditions. The chlorine to ammonia ratio, contact time, pH, chemical dosage, power requirements, and required mixing are examples of design parameters which can be obtained from pilot testing.

The data obtained during each alkaline chlorination run were recorded on a standard data sheet. Routine recordings included time, flow rate, chemical usage, pH, temperature, and ammonia concentration in each of the reaction tanks.

Test Conditions--

Based on prior laboratory bench tests and accepted practice, the following test conditions were selected.

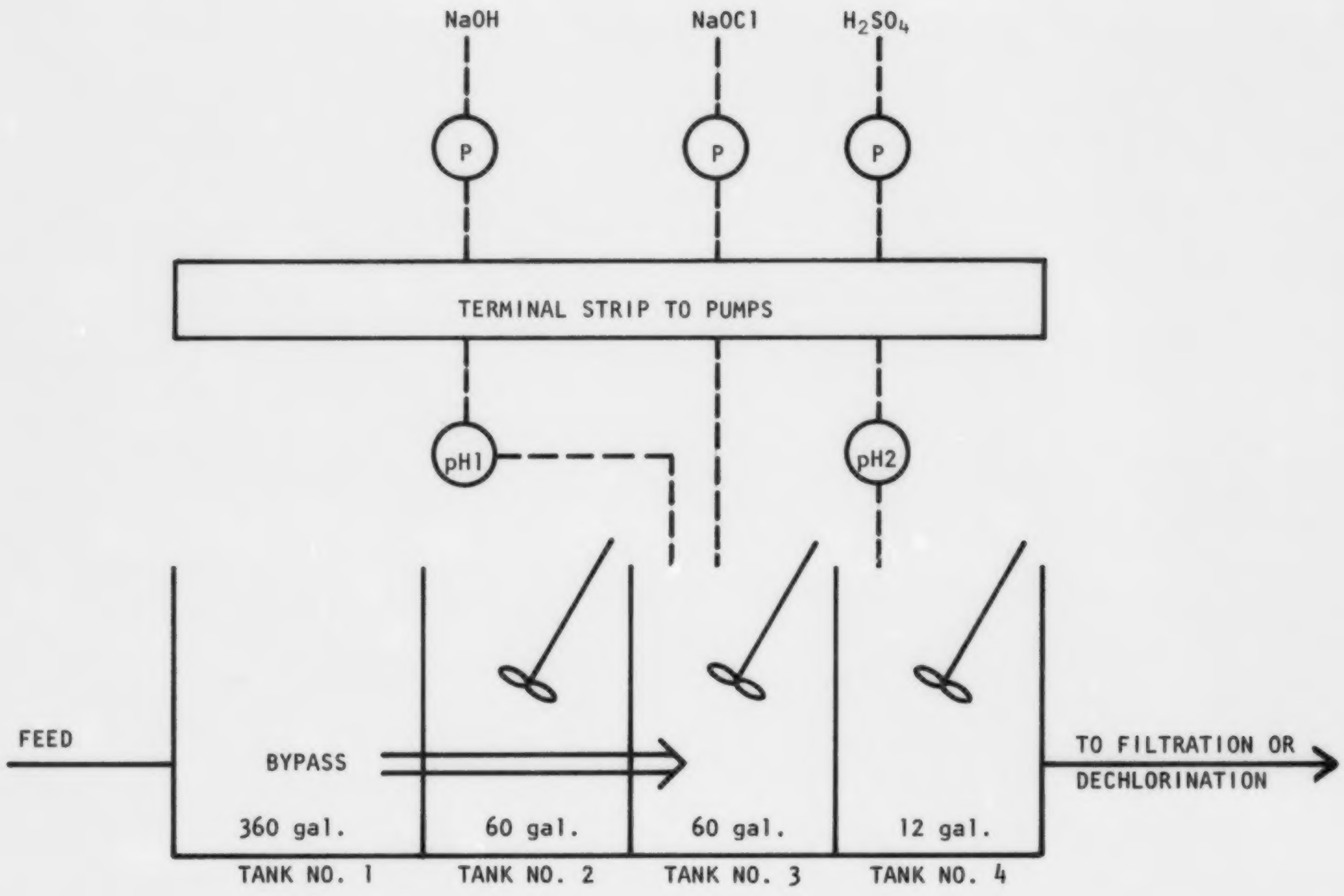

NaOH
NaOCl
H_2SO_4
P
P
P
TERMINAL STRIP TO PUMPS
pH1
pH2
FEED
BYPASS
TO FILTRATION OR DECHLORINATION
360 gal.
60 gal.
60 gal.
12 gal.
TANK NO. 1
TANK NO. 2
TANK NO. 3
TANK NO. 4

Figure 8. Alkaline chlorination system schematic.

1. Flow Rate: The flow rate was maintained at a constant 7.6 liters/min (2 gpm) for pilot testing of the raw wastewater. Corresponding detention times were 30 minutes in the cyanide removal tank and 6 minutes in the ammonia removal system.

2. pH Adjustment: The feed water (raw wastewater) pH was elevated to 11.5 in the cyanide tank and then dropped to 6.5-7.0 in the ammonia removal tank. The pH was held relatively constant by the use of pH controllers. The pH probes were checked for calibration periodically.

3. Feed Characteristics: During the study, alkaline chlorination was performed on the raw wastewater which consisted of by-product coke plant effluent. The coke plant water had been equalized prior to being fed to the pilot units.

4. Mixing: Rapid mixers were placed in each of the reaction chambers to insure adequate contact between the wastewater and the chemical applied.

5. Chlorine Application: From the bench studies, ORP was found to be the optimum control for meeting BAT limitations. An optimum ORP setting was selected to reduce BAT (non-priority pollutant) parameters to acceptable limits. During the pilot testing, the ORP setting was held relatively constant during each run to provide a uniform effluent for evaluating toxic pollutant data.

Pilot Test Procedure and Data Acquisition--
The alkaline chlorination process was run continuously while testing the raw wastewater. Before each test, an ORP setting was selected. The testing interval was called a run and assigned a number. Run lengths were generally from 8 to 24 hours. There were occasional runs of longer or shorter duration. There were several consecutive runs in which operating parameters remained the same over an extended period of time to obtain long-term operating data.

DUAL MEDIA FILTRATION

Introduction

Filtration is widely utilized for wastewater treatment both in upgrading existing conventional plants and in designs of new advanced treatment facilities. It is one of the most widely used processes for separation of wastewater solids.

In application, filtration may serve both as an intermediate process to prepare wastewater for further treatment (such as carbon adsorption) and as a final polishing step following other processes.

Granular media filtration involves passage of water through a bed of granular material with resulting deposition of solids. Eventually the pressure drop across the bed becomes excessive or the ability of the bed to remove suspended solids is impaired. Cleaning is then necessary to restore operating head and effluent quality to acceptable levels. Most filters operate on a batch basis, the entire unit being removed from service for periodic cleaning.

The time in service between cleanings is termed run length. The headloss at which filtration is interrupted for cleaning is called terminal headloss.

Filter design involves selection of the following filter characteristics:

1. Filter configuration.
2. Media sizes, depths and materials.
3. Filtration rate, liters/min/m^2 (gpm/ft^2).
4. Terminal headloss, m of water (ft of water).
5. Method of flow control.
6. Backwashing design features.

The major goal in design is to achieve effluent quality objectives at low capital and operating costs. The most important characteristic in determining capital costs is filtration rate, which fixes the filter size. Operating costs are affected primarily by filtration rate, terminal headloss, media characteristics and backwash design. The first three filter characteristics determine the cost of power for operating head and production of the filter per run. The backwash design determines cost per cleaning of operator attention, washwater pumping, air scouring (compressor operation) and treatment of dirty washwater. The cost of cleaning per unit volume treated (cost per cleaning divided by production per run) depends on all four factors.

Wherever possible, designs should be based on pilot filtration studies of the actual waste. Such studies are the only way to assure:

1. Meaningful cost comparisons between different filter designs capable of equivalent performance, i.e., producing the same output quantity and quality over the same time period.
2. Most economical selection of filter rate, terminal headloss and run length for a given media application.
3. Definite effluent quality performance for a given media application.

Pilot studies are also used for determining effects of pretreatment variations or for characterizing filterability in terms of performance attainable with a specific filter design.

The wastewater tested was alkaline chlorinated by-product coke plant wastewater.

Description of Pilot Equipment

An automated, down flow, granular media filter with an effective area of

0.09 m^2 (1.0 ft^2) was used in this study. The filter compartment internal diameter is 0.35 meters (13.6 in.) and the height is 2.1 meters (7 ft). The vessel is rated for 35,155 kg/m^2 (50 psi) operation, and is assembled in three flanged sections. The bottom section contains a filtrate compartment, separated from the filter media compartment by a false bottom. Connections for filtered product water, backwash water and air are located in the filtrate compartment. Three plastic underdrain strainers are located in the false bottom. Each strainer head measures 6.3 cm (2.5 in.) in diameter with 0.025 cm (.010 in.) slots. The strainer also had a 5.2 cm (6 in.) long air metering tube extending into the filtrate compartment. Holes in the air metering tubes provide for uniform distribution of air to each strainer during air backwash. The strainers are designed for use in the sand media without a gravel support.

Above the filtrate compartment the filter media compartment consisted of a flanged section and a flanged cover. A flanged access port is located in the lower portion of the section. Screened pressure taps are provided at 10.2 cm (4 in.) intervals, starting 7.6 cm (3 in.) from the base plate. The top cover contains connections for feed and backwash overflow.

Filtrate was collected in a 1,900 liters (500 gal.) tank to provide a continuous supply to downstream processes during filter backwash periods.

Flow to the filter was pumped by a 84.9 BTU/min. (2 HP), enclosed impeller, centrifugal pump. Backwash water was pumped from the 1,900 liters (500 gal.) tank by a 31.8 BTU/min. (3/4 HP), enclosed impeller, centrifugal pump and an air compressor was provided for backwash air scour.

Constant flow rate could be maintained with a flow control valve on the filtered effluent. Backwash could be initiated by excessive headloss, timed interval or manually. In actual practice, only the manual mode was utilized so that final pressure readings could be taken before backwashing. Once backwash is initiated, the sequence proceeds automatically with drawdown of the liquid above the filter bed, air scour, water wash, and a short idle interval to allow the media to settle. The filter is then returned to normal service. Valves for automatic functions are motor actuated.

Other instrumentation includes a filtrate flow rate recorder and a backwash flow meter. Headloss within the filter media was monitored at the pressure taps in the side of the filter vessel. Each pressure tap was valved and connected through a manifold to an array of three differential pressure meters. The range of these instruments were 2.54-63.5 cm (1-25 in.) water, 5-254 cm (2-100 in.) water and 0-42,186 kg/m^2 (0-60 psi). Headlosses within the media were always based on the pressure above the media.

Experimental Program

The objective of the pilot filter tests was to obtain sufficient information for full-scale design. Of vital interest are performance characteristics for determining effluent quality and design parameters to insure the most cost effective equipment size.

Performance characteristics include effluent quality and the consistency of effluent during varying feed conditions. The filter surface area required to process the design flow, media selection, backwash water processing requirements, feed preconditioning requirement, power requirements, and filter cleaning requirements are examples of design parameters which can be obtained from pilot testing.

Pertinent variables include the following.

1. Filtration rate, liters/min/m^2 (gpm/ft^2)
2. Feed characteristics.
    a. suspended solids, mg/l
    b. size distribution
    c. resistance to shear
3. Media selection.
    a. composition
    b. size distribution
    c. depth
4. Backwash.
    a. rate
    b. duration
    c. procedure
5. Mode of filter operation.
    a. constant head - declining rate
    b. constant head - constant rate
    c. variable head - constant rate
    d. variable declining rate
6. Terminal headloss.
7. Chemical preconditioning.

Pilot testing enables the researcher to define how these independent variables affect the following dependent variables.

1. Measurement of production.
    a. weight of solids captured per unit filter area as a function of headloss
    b. net volume of water filtered as a function of headloss
2. Filtrate quality.
3. Cause of filtration termination.
    a. headloss
    b. solids breakthrough
4. Depth of solids penetration as indicated by a headloss profile of the filter bed.
5. Effectiveness of backwash.

The data obtained during each filter run were recorded on a standard data sheet. Routine recordings included time, flow rate, headloss profiles, turbidity, pH, and temperature (in and out).

Test Conditions

Based on prior lab bench tests and accepted filtration practice, the following test conditions were selected.

1. Filtration Rate: The filtration rate was maintained at approximately 61 liters/min/m^2 (1.5 gpm/ft^2) throughout the study period. Flow was limited by upstream processes.

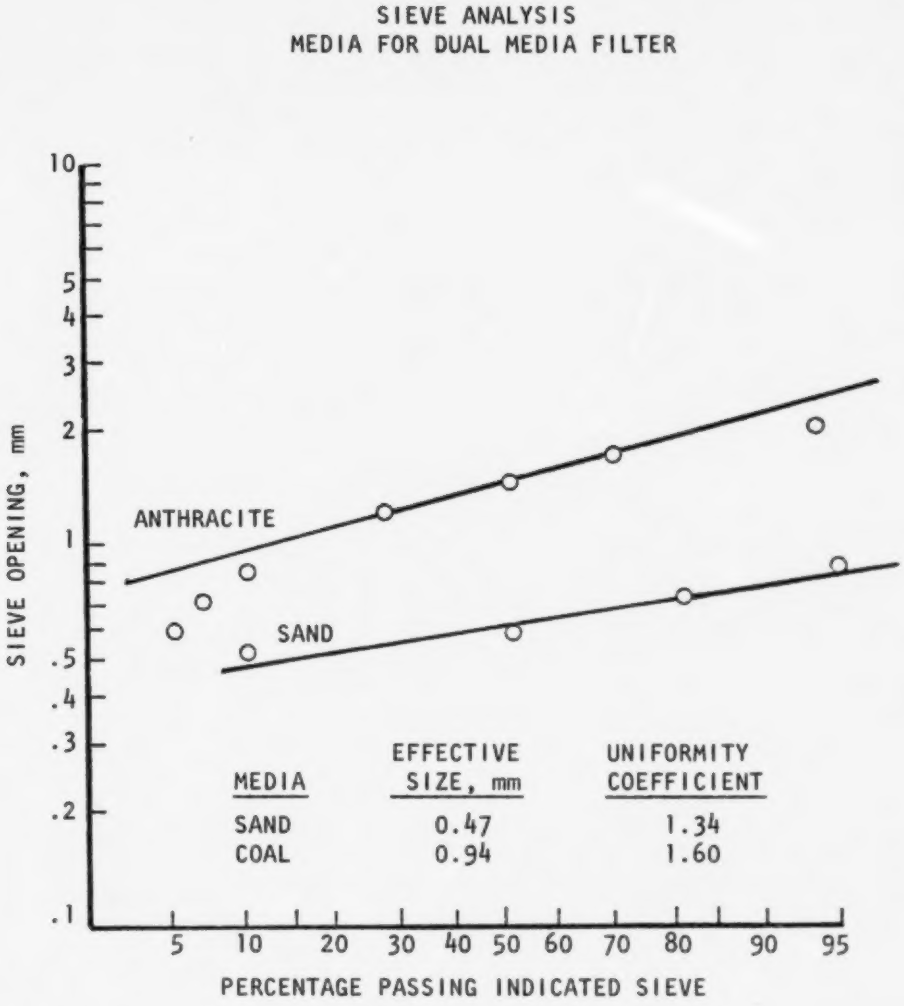
2. Feed Characteristics: This variable is determined by the process preceding the filters. During the study, the dual media filter processed alkaline chlorinated by-product coke plant effluent.

3. Filter Media: Bench scale testing early in the program indicated the best effluent quality could be achieved with dual media filtration using anthracite with an effective size of 1.0 millimeter over sand with an effective size 0.5 millimeter. For the pilot program, anthracite coal was purchased from The Reading Anthracite Coal Company, Pottsville, Pennsylvania. The purchased specification was for a material with 0.80 to 1.20 millimeter effective size and maximum uniformity coefficient of 1.65.

   Filter sand was obtained from the Red Flint Sand Company, Eau Claire, Wisconsin. The purchased specification was for 0.45 to 0.55 millimeter effective size and a uniformity coefficient of 1.4. Before loading the media, representative samples were taken by the "cone and quartering" method for sieve analysis. The results are presented in Figure 9. The anthracite media used in the pilot program had an effective size of 0.94 millimeter with a 1.60 uniformity coefficient, while the sand media effective size was 0.47 millimeter with 1.34 uniformity coefficient.

   On loading the media, a known quantity of sand was placed in the filter and backwashed at 611 liters/min/m^2 (15 gpm/ft^2) for 30 minutes. To remove fine material, the top 5 cm (2 in.) was removed. Next, a known amount of anthracite was placed on the sand and backwashed and 5 cm (2 in.) removed. The total media depth was then recorded.

4. Backwash: A relatively mild degree of backwashing was used throughout the study. The procedure was to first draw the water level down 30.5 cm (12 in.) from the overflow trough. Next, backwashing was initiated (203.7 liters/min/m^2 [5 gpm/ft^2]) while simultaneously agitating with air at 1.5 standard m^3/min/m^2 (5 scfm/ft^2) for two minutes. After turning off the air, filtered effluent was used to backwash the filter at 611 liters/min/m^2 (15 gpm/ft^2) for eight minutes. Each backwash was initiated manually so that a given filter run would correspond to a sampling interval.



MEDIA	EFFECTIVE SIZE, mm	UNIFORMITY COEFFICIENT
SAND	0.47	1.34
COAL	0.94	1.60

Figure 9. Filter media sieve analysis.

5. Mode of Filter Operation: All tests were run under pressure with constant head and constant rate.

6. Terminal Headloss: The pilot filter was operated at a pressure of about 35,256 kg/m^2 (50 psig). Data taken during each run allowed evaluation of a pressure filtration system.

Pilot Test Procedure and Data Acquisition

The filter was operated continuously throughout the study. Each interval between backwashing was called a run and assigned a number. Run lengths were generally determined by the sampling schedule and were approximately 24 hours long. There were occasional runs of longer or shorter duration as warranted by the headloss through the media. At the beginning of each run the flow controller was set to the desired rate and initial headloss readings taken. Headloss profiles through the media were recorded at intervals during the run and at termination.

Samples of feed and filtrate were composited for each run for suspended solids determination. At the termination of a run the filter was backwashed and prepared for the next run. Occasionally samples of the backwash water were taken at intervals during the water wash cycle and analyzed for suspended solids.

ACTIVATED CARBON

Introduction

Activated carbon was used to remove residual chlorine from the alkaline chlorination process, which preceded the carbon in the treatment train.

Activated carbon is a well known dechlorinating agent for water. The reaction of free chlorine with activated carbon is illustrated in equation 1,

$$C^* + HOCl \longrightarrow CO^* + H^+ + Cl^- \qquad (1)$$

where C* is an active site on the carbon surface and CO* is a surface oxide. Reactions of mono- and dichloramines (combined chlorine residual) with activated carbon are illustrated by equations 2, 3, and 4.

$$NH_2Cl + H_2O + C^* \longrightarrow NH_3 + H^+ + Cl^- + CO^* \qquad (2)$$

$$2\ NH_2Cl + CO^* \longrightarrow N_2 + H_2O + 2H^+ + 2Cl^- + C^* \qquad (3)$$

$$2\ NHCl_2 + C^* + H_2O \longrightarrow N_2 + 4H^+ + 4Cl^- + CO^* \qquad (4)$$

The ratio of chlorine to NH_3 and the pH of the wastewater determine the relative quantities of mono- and dichloramines. The reaction rate of free chlorine with activated carbon increases with decreasing pH due to the relative abundance of HOCl compared to OCl^-, and increases with temperature. The rate of dichloramine removal by activated carbon depends on the relative abundance of mono- and dichloramines. This is due to the fact that dichloramines react much faster than monochloramines. Dichloramines also react faster with activated carbon than HOCl.

Removal of free and combined chlorine also depends on many factors other than the relative abundance of free and combined species. Competition for sites on the carbon surface by chlorine residuals, organics, and suspended solids reduces the rate of chlorine removal. Pretreatment of wastewater to remove suspended solids will significantly reduce their impact on activated carbon. Organic and suspended solids reduce carbon surface area and plug carbon pores.

The size of the granular activated carbon will also affect the rate of residual chlorine removal. The surface reaction of all chlorine species is much faster than diffusion of these species to the carbon surface. Smaller particles will then minimize diffusion time and increase chlorine removal.

Contact time for chlorine removal is normally between five to ten minutes. As the carbon surface is saturated with oxides, organics, and suspended solids, a five to ten minute contact time may not be sufficient to reduce the chlorine concentration to an acceptable level (1 mg/l). When the carbon is saturated and plugged to the point where the reaction rate is not high enough to reduce the chlorine to this acceptable level in the given retention time, the activated carbon must be removed from the column.

To effectively design an activated carbon system, reliable data must be obtained to adequately size the adsorbers. The data are best obtained by running the wastewater to be treated through a pilot scale system. Analysis of the test results are then used to obtain full-scale design criteria. In this study the concentration of chlorine in the feed to the activated carbon was dependent on chlorine dose and chlorine demand in the alkaline chlorination process.

Description of Pilot Equipment

The mobile research trailers were equipped with a granular activated carbon adsorption system consisting of a series of four - 35.6 cm (14 in.) diameter columns that were designed to remove chlorine residual from filtered alkaline chlorinated raw water.

The four carbon columns were constructed of 35.6 cm (14 in.) diameter standard pipe. Influent wastewater was pumped into the bottom of the carbon columns by a self-priming pump. The flow was distributed over the carbon column by three diffusers. The carbon adsorption system was designed to operate in either the upflow or downflow mode, but for chlorine removal the upflow mode was chosen. Sample taps were located every 30.5 cm (12 in.) along the column, but samples were only taken at sample ports located 30.5 cm (1.0 ft), 91.5 cm (3 ft), and 152 cm (5 ft) from the bottom of the carbon bed. Pressure gauges are mounted at the top and bottom of each column to monitor headloss across the carbon bed. A schematic diagram of the four column adsorption system is illustrated in Figure 10.

Experimental Program

The activated carbon adsorption test was designed to obtain operating data and design criteria for a full-scale dechlorination system. The dechlorination step was required to reduce free and combined chlorine residuals from the alkaline chlorination process.

Flow rates and carbon dosages were calculated to provide test sequences of sufficient duration to obtain data which would illustrate a decrease in the carbon's capacity to reduce chlorine. The data provided design criteria to determine expected bed life.

The 35.6 cm (14 in.) diameter columns were used in the treatment train illustrated below.

Raw Wastewater → Alkaline Chlorination → Filtration Effluent → Activated Carbon → Discharge

The test trailers were provided with four columns, which were all required for this particular study. The operating parameters for the 35.6 cm (14 in.) diameter columns are outlined below.

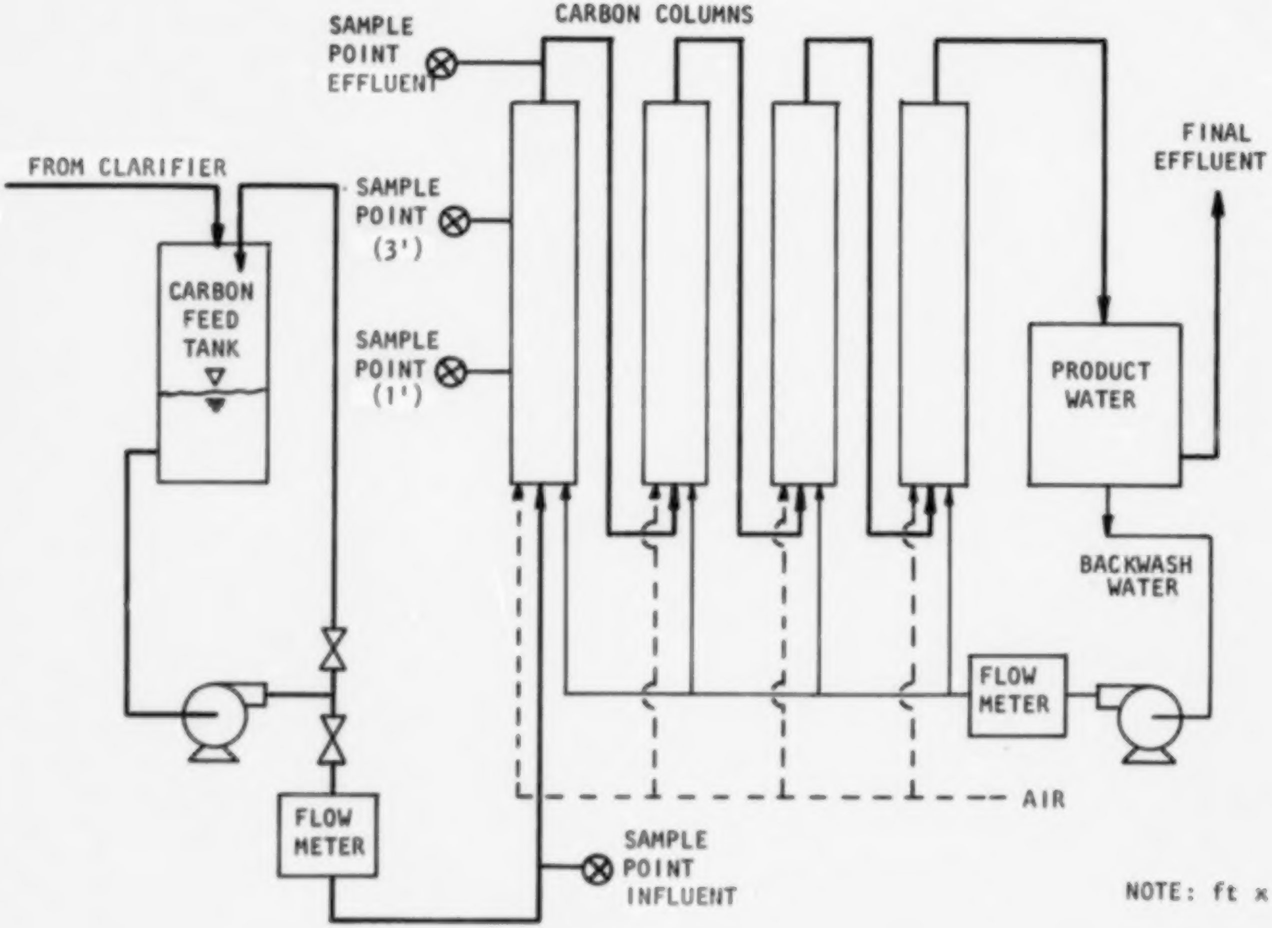
- Carbon mesh, 8 x 30
- Carbon type, virgin bituminous
- Carbon weight per column, 59 kg (130 lbs)
- Bed depth, 152 cm (60 in.)
- Linear flow rate, 0.051 $m^3/day/m^2$ (~1.25 gpm/ft^2)
- Contact time, ~30 minutes/column

- Dimensions of carbon column
  1. Column diameter, 35.6 cm (14 in.)
  2. Column height, 229 cm (90 in.)

Sampling Procedures

Grab samples were taken periodically from sample ports on all columns. These samples were analyzed on site for pH, temperature, and Cl_2 concentration. The chlorine analysis method used was the Iodometric Method which is outlined in Standard Methods for the Examination of Water and Wastewater, 14th Edition (4).

Composite samples were taken every hour for 24 hours from the 35.6 cm (14 in.)


SAMPLE POINT EFFLUENT
CARBON COLUMNS
FROM CLARIFIER
SAMPLE POINT (3')
SAMPLE POINT (1')
CARBON FEED TANK
FINAL EFFLUENT
PRODUCT WATER
BACKWASH WATER
FLOW METER
FLOW METER
AIR
SAMPLE POINT INFLUENT

NOTE: ft x 30.48 = cm

Figure 10. Granular carbon column test system.

column, or over the length of the test run, whichever was shorter. These samples were preserved accordingly and shipped back to the Rexnord Environmental Research Center analytical lab for analysis. Composite samples were tested for suspended solids, color, CN_T, CN_A, phenol, NH_3, BOD, sulfide, TDS, and chloride. Grab samples were also collected for oil and grease analyses. Routine samples were taken several times daily on site for pH, temperature, and chlorine residual. Included in this group of parameters are the six pollutants which are limited by BAT (non-priority pollutant) effluent guidelines for by-product coke wastewater discharge.

SODIUM BISULFITE

Introduction

Sodium bisulfite was a second technology investigated to remove residual chlorine from the upstream alkaline chlorination system. In this wastewater application, sodium bisulfite will react with chlorine to form sodium hydrogen sulfate and hydrochloric acid according to the following equation:

$$NaHSO_3 + Cl_2 + H_2O \rightarrow NaHSO_4 + 2HCl$$

Theoretically about 1.40 parts of sodium bisulfite are required to remove 1 part chlorine. Solid sodium bisulfite is of the anhydrous form and has the formula $NaHSO_3$. The commercial product used in the study consisted almost entirely of $Na_2S_2O_5$ known as sodium metabisulfite or sodium pyrosulfite, which is the dehydrated derivative of two sodium bisulfite molecules.

Description of Pilot Equipment

The pilot sodium bisulfite treatment system consisted of a 227 ℓ (60 gal.) reaction tank, a stock solution tank, a chemical feed pump, and a rapid mixer.

Experimental Program

The sodium bisulfite experimental program was designed to obtain the design information necessary for scale-up to a full size treatment system. The objective of testing was to reduce influent chlorine concentrations to <1 mg/l. The treatment train investigated is illustrated below:

Raw Wastewater → Alkaline Chlorination → Sodium Bisulfite Dechlorination → Filtration → Discharge

Chemical dosages were determined from bench scale tests and field conditions and were dependent on chlorine levels in the alkaline chlorinated effluent.

Feed solution was prepared by adding 15.2 kg (33.4 pounds) of solid sodium metabisulfite to 379 liters (100 gal.) of water. This yielded a feed concentration of 40 mg/ml. Care was taken to store the sodium metabisulfite in a closed, dry container due to its hydroscopic nature.

The theoretical required dose is about 1.4 parts sodium bisulfite per part of chlorine. Dosages varying from 0.35:1 to 4.05:1 (sodium bisulfite: chlorine) were investigated. Detention time during the study remained constant at 30 minutes. Complete mixing was used at all times.

Grab samples were taken periodically of the influent and effluent for pH, chlorine residual, and temperature. The chlorine analysis method used was the Iodometric Method which is described in Standard Methods (4).

Composite samples were also collected for 24 hour intervals and analyzed for various BAT parameters during the test period.

SECTION 6

COKE PLANT DATA EVALUATION

INTRODUCTION

This section describes the treatment technologies evaluated in this study and presents a summary of the findings at the coke plant research site. For each technology investigated [alkaline chlorination, filtration, and dechlorination (activated carbon and sodium bisulfite)], a general section has been provided for the process introduction, a presentation and discussion of the pilot study results, a full-scale system description and full-scale system costs and space requirements.

The field study consisted of an extensive sampling and analytical program. A summary of all analytical results obtained during the study is presented in Appendices B-2 and B-3. A separate discussion on the sampling and analytical procedures used in the study is presented below.

Lab Quality Control

Samples taken during the study period consisted of grab and 24 hour composites. Grab samples were taken for parameters such as oil and grease. Composite samples were obtained by collecting hourly discrete samples using ISCO automatic samplers over 24 hour periods.

Throughout the sampling program, the samples were iced during collection and shipment. Pertinent preservation methods in accordance with EPA (3) were performed in the field immediately after collection. Samples for Biochemical Oxygen Demand (BOD) were split and submitted to a local laboratory. The remaining samples were packaged, iced, and sent to the Rexnord Inc. Environmental Research Center (ERC) laboratory in Milwaukee, Wisconsin. Chances of sample mis-labeling were eliminated by use of unique sample identification numbers, a field sample log, and the ERC analytical laboratory sample log. The ERC laboratory also maintains a quality assurance program.

Table 15 presents the calculated population standard deviations for all duplicate analyses performed during the study. The duplicate analyses have been divided into concentration ranges or populations to better illustrate the change in precision with concentration.

Method accuracy was monitored throughout the study using standards and spiked samples. Method accuracy, shown as percent recovery, is listed for all major parameters in Table 15. Standard deviations and percent recoveries

TABLE 15. SUMMARY OF STATISTICAL EVALUATION OF LABORATORY QUALITY CONTROL ANALYSIS

Parameter	Concentration range, mg/l	Mean mg/l	Coefficient of variation	Standard deviation	Percent recovery
SS	0-50	27	6.91	1.9 (33)[1]	
	51-100	71	4.33	3.1 (45)	
	101-250	162	3.90	6.3 (32)	
	>250	9,683	3.09	299.2 (27)	
	30-33				110.0
	236-239				101.2
	548-572				95.8
TDS	1-10,000	3,237	0.52	17.0 (1)	
	>10,000	16,028	0.20	32.2 (4)	
	54-57				105.6
	323-338				95.6
	487-502				97.0
TS	1-1,000	4,945	0.45	22.3 (4)	
	>1,000	22,231	0.53	117.7 (16)	
CN_T	0-1.0	0.63	1.13	0.01 (3)	
	>1.0	85	2.19	1.9 (4)	
	0.225-0.300				98.2
	0.65-1.00				65.0
	4.3-5.0				86.0
	88-100				91.0
NH_3	0-15	10	1.97	0.2 (9)	
	16-100	30	2.04	0.6 (7)	
	>100	503	2.64	13.3 (12)	
	0.90-1.00				90.0
	1.05-1.13				92.9
	1.70-1.80				105.8
	5.9				100.0
	12.8-13.4				95.5
	14.8-16.3				90.8
	24.0-24.6				102.5
	33.8-35.8				94.4
	437				90.0
	1,568				92.3
TKN	0-250	92	0.99	0.9 (4)	
	>250	478	1.63	7.8 (4)	
	0.89-0.90				98.9
	1.13-1.20				106.2

(continued)

TABLE 15. (continued)

Parameter	Concentration range, mg/l	Mean mg/l	Coefficient of variation	Standard deviation	Percent recovery
TKN	3.9				100.0
	10.2-10.95				93.2
	11.0-11.7				94.0
	13.4-14.6				91.7
	16.8-17.5				96.0
	33.7-36.9				91.3
	48				100.0
NO_2/NO_3	0.55-0.58				96.0
	0.89				100.0
	1.03-1.04				100.9
	1.08-1.14				100.5
O&G	57-59				96.6
Phenol	0-100	95	4.47	4.2 (1)	
	0.13				100.0
	0.30				100.0
	0.35-0.36				97.2
S	0-30	18.75	1.95	0.4 (2)	
	41.6-43.1				103.6
TOC	138-145				99.9
Cl	35-37				101.5
	53-55				103.8
	122-123				99.2
	219				100.0
	230				100.0
	900-925				102.7
	2310-2333				99.0
	5038-5136				100.5

[1] Indicates the number of standard deviations used to calculate population standard deviation.

for all parameters are similar to the precision and accuracy limits given in Standard Methods, indicating that each respective procedure was in control during the test program.

All analytical procedures used during the study period were referenced from Standard Methods for the Examination of Water and Wastewater (4). The equipment used and the specific reference for all analytical procedures is presented in the following list.

1. pH - pH meter, Standard Methods, p. 460.
2. Turbidity - Hach Model 2100A turbidimeter, Standard Methods, p. 132.
3. Color - Hellige Aquatester with color comparison discs calibrated at 0, 5, 10, 20, 30, 40, 50, 60, and 70 APHA color units. Waste samples were filtered and diluted with distilled water (if necessary) to reduce color to less than 70 APHA units. When the color of the sample was clearly between that of two color discs, the values for both color discs were recorded. For example, the term 0/5 means that the color of the sample was more than 0 APHA units, but less than 5 APHA units. For plotting and calculation purposes, the value midway between the two color discs was used. Standard Methods, p. 64.
4. BOD - Standard Methods, p. 543.
5. Alkalinity - Standard Methods, p. 278.
6. Total Organic Carbon (TOC) - Beckman Model 915 TOC Analyzer, Standard Methods, p. 532.
7. Suspended and Volatile Suspended Solids - Standard Methods, p. 94 and 96.
8. Oil and Grease - Standard Methods, p. 515.
9. Total Phosphate - Standard Methods, p. 476 and 624.
10. Total Dissolved Solids - Standard Methods, p. 93.
11. Sulfate - Standard Methods, p. 496.
12. Chloride - Standard Methods, p. 304.
13. Conductivity - Standard Methods, p. 71.
14. Metals - Na, Si, K, Mn, Fe, Al, Ca, Mg - Standard Methods, p. 144.
15. Fluoride - Standard Methods, p. 391.
16. Chemical Oxygen Demand - Standard Methods, p. 550.
17. Ammonia Nitrogen - Standard Methods, p. 407.

Description of Cost Analysis

Delivered costs for the various principal pieces of equipment were obtained from vendor quotations and from a recent edition of the Dodge Manual for Building Construction Pricing and Scheduling(5). The total plant cost includes all of the funds required to procure equipment, land and buildings in addition to funds required to design, build and bring the facility to acceptable operation. To determine the total plant cost, the Chilton method (5) of cost estimation was utilized. The Chilton method uses a factored approach. That is, the delivered costs of the principal pieces of equipment in the system are summated and then multiplied by various factors appropriate for the type of system being built. Factors for most items have a selection range which requires the judgement of the estimator to make an appropriate selection within the range.

Similar factors were selected for all systems which permits consistent comparison between systems.

The particular Chilton factors used for the various treatment methods and a costing example are listed in Appendices C and D.

The principal items that are included in the cost estimates are the following.

1. Capital Equipment
2. Buildings
3. Land Acquisition and Site Preparation
4. Utilities and Yard Services (air, water, electricity, etc.)
5. Engineering Services
6. Contractors Fees
7. Contingencies
8. Winterization (excluding exposed pipe insulation)

The assumptions that were used in preparing the cost estimates are listed in Table 16.

TABLE 16. ASSUMPTIONS USED TO DEVELOP COST AND DESIGN FIGURES FOR FULL SCALE SYSTEMS

1. Electric costs: $0.03/KWH

2. Capital amortization: 7.125 percent
   20 year service life

3. Labor: $19,000/year skilled
   $16,000/year unskilled

4. The costs developed are exclusive of supervisory and laboratory expenses, personnel overhead, fringe benefits, indirects (interest on capital during construction, etc.), exposed pipe insulation, sludge handling and disposal, etc.

5. All prices are effective as of May 1, 1980.

The capital cost information presented in this report has been prepared from a minimum of flow sheet and equipment data. Using the definition found in Perry's "Chemical Engineers' Handbook" (2), this type of estimate would be termed a "study estimate", having an accuracy of ±30 percent.

RESULTS OF THE ALKALINE CHLORINATION STUDY

Data Evaluation

During the alkaline chlorination pilot study, the reaction tank oxidation-reduction potential (ORP) was maintained as steady as possible to permit the acquisition of long term analytical data on conventional and toxic pollutants. For a typical test run, a grab sample of the raw wastewater was bench tested in the field to optimize the ORP setting. The pH of a one liter (0.26 gal.) sample was elevated to 11.5 and sodium hypochlorite was added to excess. The contents were mixed for 15 minutes, then the pH was lowered to 7.0 and mixing continued for about 2-3 minutes. The effluent cyanide and ammonia were measured and the ORP was recorded. The proper ORP setting was selected by the field operator and the sodium hypochlorite usage was monitored. Previous laboratory and field bench testing had determined that if a proper ORP setting was maintained, then all oxidizable parameters of concern could be reduced to below future BAT levels (exclusive of priority pollutants). As mentioned previously, the ORP setting was held as steady as field conditions would permit during the toxic pollutant collection period. However, on weekends no samples for toxics were collected and the operator was free to vary the ORP over a wide range, thereby bracketing the optimum setting. This information was important for later use in designing the full-scale system.

As the coke plant wastewater entered the pilot system's first reaction chamber, it was completely mixed and the pH was raised with sodium hydroxide to 11.5 using a pH controller. Sodium hypochlorite was also added to this chamber in excess. The primary chemical reaction that occurred was the conversion of cyanide to cyanate. Routine monitoring for cyanogen chloride (a strong irritant formed as an intermediate reaction) was performed using a Dreager gas detector tube. Airborne cyanogen chloride concentrations were kept below detectable levels during the study by using the research trailer's exhaust system. Wastewater detention time in the cyanide oxidation chamber was maintained at 30 minutes.

Following cyanide destruction, the wastewater passed into a second completely mixed reaction chamber where the pH was lowered to about 7.0 using 66° Be' sulfuric acid. Constant pH was maintained using the pH controller provided with the system. In the presence of excess chlorine, ammonia was oxidized to nitrogen gas and other harmless byproducts. The contact time allowed in this reaction tank was 6 minutes, which was sufficient to complete the ammonia oxidation. The exiting wastewater was then post-treated by filtration and dechlorination.

The alkaline chlorination system was run continuously over the test period to provide 24 hour composite samples for both conventional and toxic analysis. The composite samples were collected hourly on the influent and effluent using iced, automatic samplers. At the end of a sampling period, the samples were preserved and refrigerated. Several times a week, the samples were packaged, iced and shipped back to the Rexnord Environmental Research Center in Milwaukee for analysis. Routine analytical parameters included ammonia, cyanide-T, phenol, sulfide, thiocyanate, oil and grease, dissolved solids, TOC, nitrite/nitrate and TKN. On-site analysis was routinely performed by the field operator for pH, chlorine residual, temperature and ammonia (probe method for field control).

Typically, the ORP level was held between 850 mv and 950 mv, however extreme variations in the influent wastewater contaminant strength prevented maintaining a constant oxidation-reduction potential (ORP) for any considerable length of time. An example of the influent ammonia variability is shown in Figure 11. Feed ammonia concentration ranged from 100 mg/l to a high of almost 2,200 mg/l during the study. This is considerably higher than the BPT guideline concentration for ammonia of 125 mg/l. However, effluent ammonia was typically less than 10 mg/l, and often less than 5 mg/l.

To help in dampening the effects of influent ammonia, cyanide, phenol and thiocyanate variability, the ORP controller provided with the pilot system was used continuously. The ORP probe was placed in the alkaline chlorination system exit chamber. A continuous feed-back control loop maintained constant ORP by opening or closing a solenoid valve which provided the source of chlorine feed to the front end of the system. However, due to the extremely wide variation in chlorine demand, it was necessary to modify the system by adding a second chemical feed pump. This pump was run continuously, adding a constant amount of sodium hypochlorite to the reaction chambers. Differences between the chlorine demand and the desired level of operation were then compensated for by using the chemical pump connected to the ORP controller. However, even with the use of this modified chlorine addition system, it was not uncommon for the chemical feeders to be unable to keep up with the chlorine demand of the raw wastewater which resulted from a sudden discharge of highly chemical oxidizable waste by the coke plant. If the operator happened to be watching the ORP indicator at the time of the upset, a manual adjustment was made to increase (or decrease) the capacity of the second pump to maintain constant ORP. However, this was not always possible and as a result, fluctuations did occur in the ORP.

Appendix B-4 presents the entire data analysis for all samples collected during the alkaline chlorination pilot study. In addition to the BAT (non-priority pollutant) parameters tested, the table also provides information on dissolved solids, chlorides, color, nitrite/nitrate, BOD and TOC values observed during the study. A summary of Appendix B-4 is shown in Table 17. In all, a total of 40 runs were performed during the test period. Runs 1-22 were conducted prior to the Christmas holidays, with post-treatment consisting of filtration and activated carbon dechlorination. Runs 23-40 were conducted after the holidays with post-treatment being dechlorination using sodium metalbisulfite and filtration with polymer addition. The effluents shown in Table 17 represent the values obtained at the exit from the alkaline chlorination process. Samples were routinely collected at different points in the treatment train and these analyses are included as part of Appendix B-4.

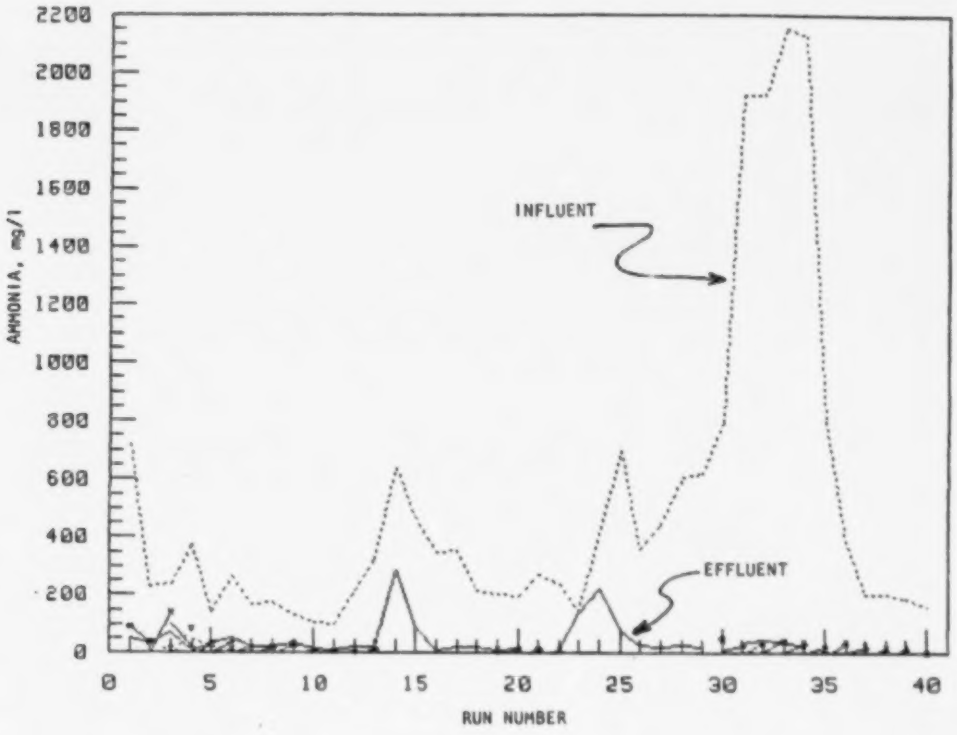


Figure 11. Influent and effluent ammonia concentration versus run no. - alkaline chlorination treatment train.

TABLE 17. ALKALINE CHLORINATION DATA SUMMARY

Run No.	ORP mv	pH, Units		Suspended Solids, mg/l		Phenol, mg/l		Ammonia, mg/l		Sulfide, mg/l		Cyanide$_T$, mg/l		Thio-Cyanate, mg/l		Oil & Grease, mg/l	
		Inf.	Eff.	Inf.	Eff.	Inf.	Eff.	Inf.	Eff.	Inf.	Eff.	Inf.	Eff.	Inf.	Eff.	Inf.	Eff.
1	850	8.7	6.8	263	110	98	0.4	717	2	26	<0.2	100.0	11.6	245	3	-	-
2	800	8.1	6.5	69	15	80	0.3	224	4	27	<0.2	130.0	9.4	320	<1	-	-
3	840	8.8	5.9	48	28	96	0.11	241	1	19	<0.2	125.9	0.2	205	<1	3	3
4	840	8.2	6.3	40	34	110	0.2	370	1	20	<0.2	100.7	0.3	200	<1	-	-
5	700	8.6	6.1	35	19	124	1.5	142	2	14	6.8	83.8	3.6	155	<1	-	-
6	700	8.7	6.5	152	102	70	0.4	260	3	26	<0.2	70.7	3.8	260	<1	6	15
7	750	8.6	6.3	57	48	-	-	167	3	-	-	64.0	1.0	-	-	-	-
8	900	8.7	6.7	58	34	-	-	174	3	-	-	69.5	4.0	-	-	-	-
9	700	10.0	6.7	55	14	76	0.6	126	2	26.9	<0.2	145.0	3.8	300	14	3	3
10	900	9.6	6.0	65	49	68	0.35	106	2	24.8	<0.2	267.5	I	300	45	-	-
11	960	10.8	6.4	97	35	-	<0.01	101	2	24.6	<0.2	99.6	I	290	10	-	-
12	960	9.5	6.3	52	24	80	0.55	214	3	25.9	<0.2	97.7	3.7	290	8	-	-
13	950	8.8	6.6	48	11	850	0.5	320	4	24.8	<0.2	79.7	7.9	300	15	10	-
14	500	8.8	6.2	-	-	-		637	270	-	-	58.0	8.7	-	-	-	-
15	600	8.8	6.2	-	-	-	-	467	4.5	-	-	63.0	8.2	-	-	-	-
16	700	8.8	6.3	-	-	-	-	347	3	-	-	47.3	10.5	-	-	-	-
17	800	8.9	6.2	-	-	-	-	355	2	-	-	56.6	10.3	-	-	-	-
18	1,000+	9.1	6.2	-	-	-	-	216	4	-	-	75.0	5.8	-	-	-	-
19	920	9.1	6.2	171	129	80	0.7	202	2	27.3	<0.2	83.8	13.0	320	3	-	-
20	940	9.3	6.9	123	139	80	1.4	193	3	25.7	<0.2	83.0	12.9	295	45	11	8
21	940	8.8	6.4	104	71	69	1.4	269	3	27.3	<0.2	131.3	6.8	275	8	-	-
22	940	8.7	6.4	64	71	78	3.0	235	2	24.4	<0.2	105.0	8.9	275	23	-	-
23	500	8.5	7.1	-	-	-	-	140	64	-	-	-	-	-	-	-	-
24	600	8.4	-	-	-	-	-	409	185	-	-	-	-	-	-	-	-
25	700	6.2	7.2	-	-	-	-	700	5	-	-	-	-	-	-	-	-
26	820	8.4	7.1	-	-	-	-	358	<1	-	-	-	-	-	-	-	-
27	900	8.8	7.05	-	-	-	-	442	<1	-	-	-	-	-	-	-	-
28	950	8.4	-	-	-	-	-	610	<1	-	-	-	-	-	-	-	-
29	990	8.0	6.4	-	-	-	-	622	1	-	-	-	-	-	-	-	-
30[a]	900	7.4	7.5	67	6	-	-	800	<1	-	-	64.0	0.8	240	4	-	-
31	780	3.8	6.5	116	3	130	0.05	1,925	<1	26	<0.2	44.4	I	255	45	138	43
32	800	3.8	7.2	116	1	130	<0.05	1,925	<1	26	<0.2	44.4	I	255	<1	-	-
33	800	4.1	7.0	247	4	-	-	2,150	-	-	-	40.5	I	250	8	-	-
34	800	8.0	6.4	187	9	280	<0.05	2,130	<1	260	<0.2	4.7	I	2	3	147	14
35	820	6.8	6.5	361	2	38	0.3	800	<1	11.6	<0.2	14.1	I	185	<1	139	11
36	800	9.3	7.2	66	6	154	1.4	390	2	-	-	88.2	9.4	260	3	-	-
37	850	9.0	6.6	52	7	156	0.6	203	1	154	6.6	99.2	9.4	215	3	-	-
38	850	9.6	7.0	71	<1	120	1.0	204	4	106	36.1	127.5	10.3	315	3	-	2
39	900	9.9	7.0	60	1	170	0.6	184	1	87.8	99.8	85.0	4.7	460	5	40	2
40	1,000+	10.0	-	26	1	130	0	161	<1	38.7	<0.2	87.4	I	370	4	40	2

Note: I indicates interference.
[a] Runs 30-40 alkaline chlorinated effluent was dual media filtered.

Table 17 shows that oxidation-reduction potential settings from 500 mv to 1,000 mv were investigated with the majority of the test runs performed at an ORP of about 900 mv. Figure 12 shows that effluent ammonia was reduced significantly as the ORP setting was increased. Operating the ORP controller in the 850 mv to 950 mv range provided optimum treatment. At lower settings, effluent parameters exceeded BAT (non-priority pollutant) limits while operation at above 950 mv resulted in extremely high chlorine residuals, indicative of chemical wastage.

Table 17 also summarizes the analytical data obtained from each run for the non-priority pollutant BAT parameters of concern. Comparing the data to the BAT limitations for the coke plant shown in Table 18, it is evident that several of the test runs met the BAT requirements for all non-priority pollutant parameters. Many additional runs also met all non-priority pollutant BAT limits except for cyanide-T. The effluent ammonia numbers listed in Table 17 are based on field analysis by the specific ion probe method. Samples that were collected in the field, preserved and returned to the laboratory for analysis exhibited an artifically high ammonia concentration. A brief explanation is presented below.

In the first stage alkaline chlorination process, cyanide was oxidized to cyanate under alkaline conditions. The wastewater was then neutralized for ammonia removal. Following collection, the samples for ammonia analysis were preserved by acidification as specified in the U.S. EPA's "Methods of Chemical Analysis for Water and Wastewater"(3). These samples also contained significant concentrations of cyanate. Cyanate hydrolyzes to ammonia at low pH according to the following reaction (4):

$$2NaCNO + H_2SO_4 + 4H_2O \rightarrow (NH_4)_2SO_4 + 2NaHCO_3$$

Thus, 1 mg/l of ammonia is produced for each 3 mg/l cyanate present. As a result, higher than actual ammonia concentrations were observed in the laboratory samples. A comparison of the laboratory versus field ammonia values is shown in Appendix B-5.

As shown in Table 19, the average influent wastewater analytical values obtained at the study site were further above the BPT requirements than would be expected under normal operation of the existing pretreatment equipment. For example, average phenol concentration exceeded the BPT limit by 140 mg/l or 71 times. Similarly, average ammonia concentration was more than 4 times the BPT requirement and at one time during testing, BPT was exceeded by 17 times. Oil and grease and suspended solids were also well above specified BPT levels. Equipment within the by-products plant led to these unusually high pollutant parameter levels. Although treatment of this high strength waste was possible, the most economical and logical approach to meeting future BAT guidelines would be to provide a higher degree of pollutant removal in the pre-treatment system.

Alkaline chlorination was found to be effective in reducing influent Total Kjeldahl Nitrogen by about 90 percent. Chlorination also significantly

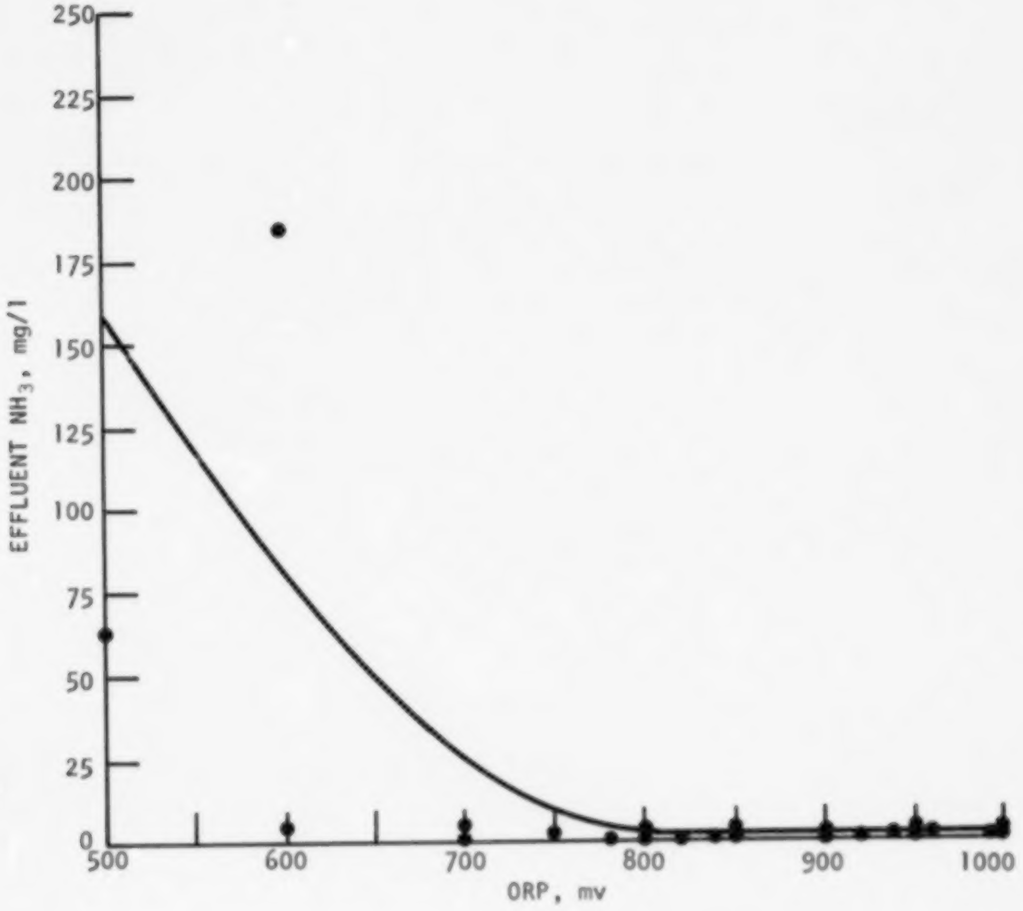


Figure 12. Effluent ammonia versus oxidation-reduction potential.

TABLE 18. BAT LIMITATIONS FOR COKE PLANT INVESTIGATED[a]

Parameter	BAT Limitations mg/l	BAT Limitations lb/day
Ammonia	13.4	27.6
Cyanide, Total	0.33	0.69
Oil & Grease	13.4	27.6
Phenol	0.27	0.55
Sulfide	0.4	0.83
Suspended Solids	27	55.5
Thiocyanate	200	402

[a] From "Development Document for Proposed Effluent Limitations Guidelines and Standards for the Iron and Steel Manufacturing - Point Source Category-By-Product Cokemaking Subcategory - EPA 440/1-79-024a (1).

TABLE 19. COMPARISON OF BPT EFFLUENT LIMITATION GUIDELINES TO ACTUAL PLANT EQUALIZATION BASIN VALUES OBSERVED DURING THE STUDY PERIOD

Parameter	BPT[a] Limitation	Analytical value from research site: Average	Analytical value from research site: Range
Cyanide, T	29 mg/l	85.2 mg/l	4.7-267.5
Phenol	2 mg/l	142 mg/l	68-850 mg/l
Ammonia	123 mg/l	506 mg/l	101-2,150 mg/l
Oil and Grease	15 mg/l	54 mg/l	3-147 mg/l
Suspended Solids	49 mg/l	103 mg/l	26-361 mg/l
pH	6.0-9.0	--	3.8-10.8

[a] From Reference No. 1.

decreased TOC and BOD. As shown graphically in Figure 13, the alkaline chlorination process increased dissolved solids of the waste due to the addition of chemical salts. During the test period, influent dissolved solids averaged 4,300 mg/l while the alkaline chlorination average effluent concentration was 19,900 mg/l. This represents an almost five fold increase through the system. Figure 13 also shows chloride increase through the process. The chloride increase across the activated carbon column can be attributed to the breakdown of chlorine on the activated carbon surface. Values of selected parameters as they passed through the alkaline chlorination treatment train are shown graphically in Figure 14 for a typical run (Run No. 20). For example, the coke plant wastewater pH was elevated to 11.5 as it entered the cyanide removal tank resulting in the oxidation of cyanide to cyanate. The increase in pH and corresponding decrease in cyanide concentration are shown. The graph also shows that as the wastewater was neutralized in the presence of excess chlorine, ammonia concentration was significantly reduced. Chlorination also slightly increased the suspended solids of the coke plant wastewater, probably the result of hydroxide floc formation which did not totally resolubilize upon neutralization. The suspended solids were effectively removed by the dual media filter.

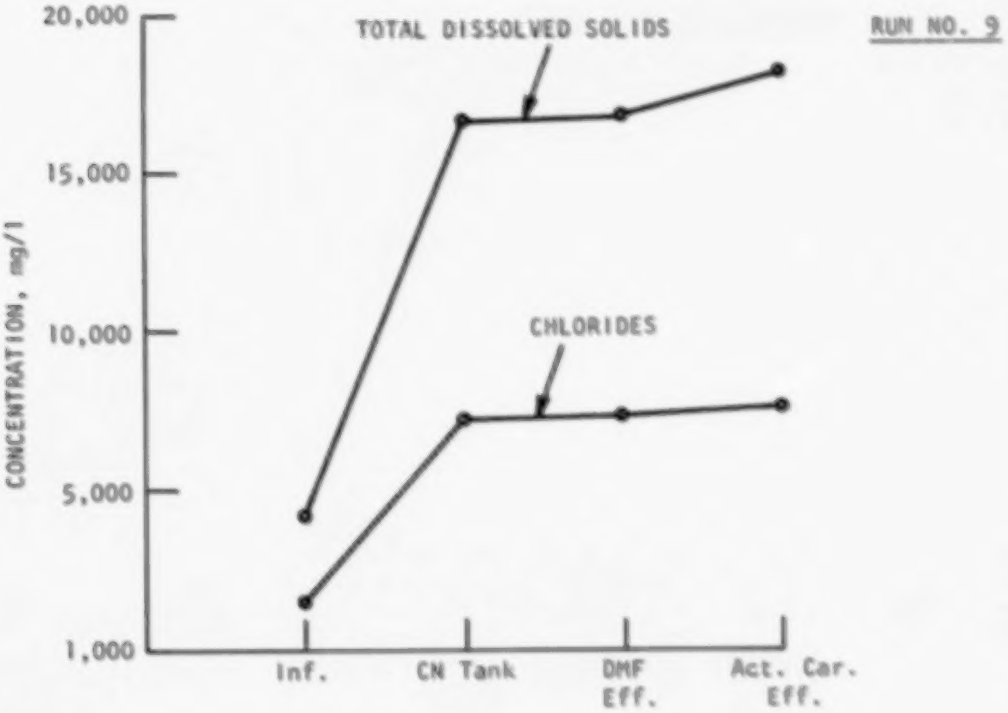


Figure 13. Plot showing increase of dissolved solids and chloride through alkaline chlorination process.

RUN NO. 20

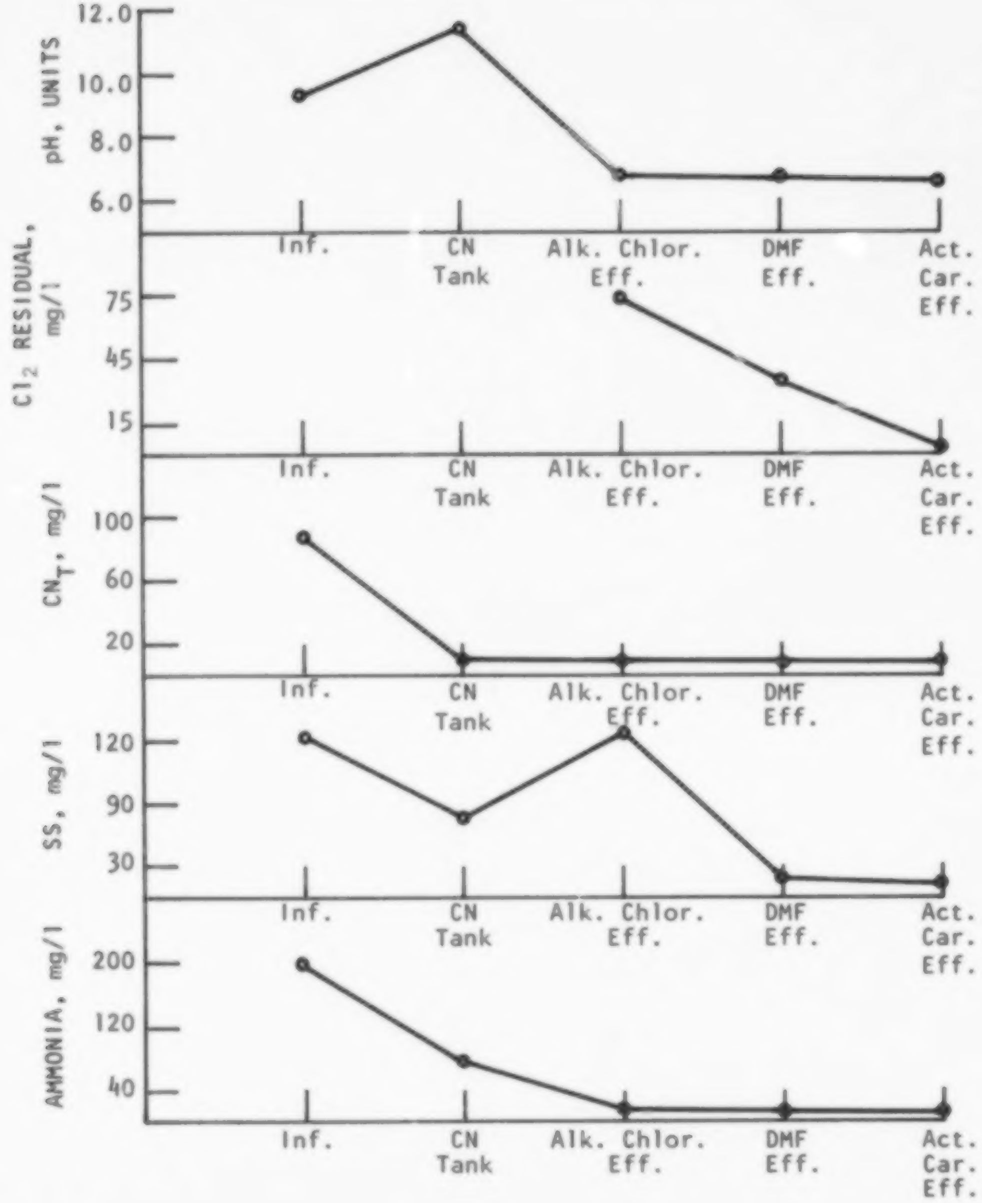


Figure 14. Values of selected parameters through the alkaline chlorination treatment train.

A comparison of selected alkaline chlorination run effluents to non-priority pollutant BAT limitations is presented in Table 20. All of the runs were performed at an ORP between 820-1,000 mv. It is apparent from Table 20 that BAT limits can be routinely met with the exception of total cyanide. The presence of complexing agents in the coke plant effluent may have prevented complete oxidation of the cyanide-T by chlorine. Based on the pilot results, a full scale treatment system using alkaline chlorination would periodically exceed its NPDES permit cyanide-T limitation when BAT guidelines would go into effect. However, it should be remembered that the average influent cyanide-T value of the wastewater tested was approximately three times the BPT limit (30 mg/l) and cyanide-T values of nine times BPT values were observed. It is unknown if BAT cyanide-T levels could be consistently met if better pre-treatment were provided. Cyanide-A values for the effluent were typically <0.05 mg/l.

Chlorine residual as a function of oxidation-reduction potential is shown in Figure 15. The graph (for illustrative purposes only) shows that high chlorine residuals were present at ORP settings of less than 650 mv. As the ORP was increased, chlorine residual decreased and breakpoint chlorination occurred. At ORP settings above 950 mv, free chlorine was available and chlorine residual increased with increasing oxidation-reduction potential. For design purposes, an ORP setting should be selected that would provide sufficient chemical to reach breakpoint chlorination for ammonia oxidation, but have a minimal amount of excess free chlorine. Previously presented data have indicated that these conditions could be met at an ORP setting of about 900 mv. A summary of chlorine residuals for each of the test runs is shown in Appendix B-6.

Acid and caustic chemical usage was monitored throughout the study and the volumes used for each run are shown in Appendix B-6. Caustic usage (25% NaOH) averaged 6.2 liters/1,000 liters treated wastewater (6.2 gal./1,000 gal. treated wastewater) to raise the feedwater pH to 11.5 with a range from 0.35 liters/1,000 liters treated wastewater (0.35 gal./1,000 gal. treated wastewater) to 23.8 liters/1,000 liters treated wastewater (23.8 gal./1,000 gal. treated wastewater). The highest usage occurred when the influent coke plant wastewater pH dropped to less than 3.5 units. Acid consumption (66° Be' H_2SO_4) was quite consistent during the pilot study ranging from 0.46 liters/1,000 liters treated wastewater (0.46 gal./1,000 gal. treated wastewater) to 6.0 liters/1,000 treated wastewater (6.0 gal./1,000 gal. treated wastewater). The average acid usage was 1.45 liters/1,000 liters treated wastewater (1.45 gal./1,000 gal. treated wastewater) over the study period. The acid was used to lower the pH of the cyanide treated wastewater from pH 11.5 down to about pH 7.0. Sodium hypochlorite usage is also shown in Appendix B-6. Consumption was dependent on the oxidizable material in the feedwater (which was quite variable during the study) and the ORP setting. The amount of sodium hypochlorite used ranged from 14.7 liters/ 1,000 liters treated wastewater (14.7 gal./1,000 gal. treated wastewater) to 148.2 liters/1,000 liters treated wastewater (148.2 gal./1,000 gal. treated wastewater) and averaged 52.3 liters/1,000 liters treated wastewater (52.3 gal./1,000 gal. treated wastewater). This high consumption of chlorine

TABLE 20. COMPARISON OF SELECTED ALKALINE CHLORINATION RUN EFFLUENTS TO NON-PRIORITY POLLUTANT BAT LIMITATIONS

Run No.	ORP mv	NH , mg/l	CN_T, mg/l	O&G, mg/l	Phenol, mg/l	S^-, mg/l	SS, mg/l	SCN, mg/l
3	840	1	0.2	3	0.11	<0.2	28	<1
4	840	1	0.3	-	0.2	<0.2	34	<1
10	900	2	I	-	0.35	<0.2	49	45
11	960	2	I	-	<0.01	<0.2	35	10
35	820	<1	I	11	0.3	<0.2	2	<1
40	1,000+	<1	I	2	0	<0.2	1	4
BAT Limitations[a]		13.4	0.33	13.4	0.27	0.4	27	200

I: Interference in the standard cyanide test caused by the presence of an oxidizing agent.

[a] From Reference No. 1.

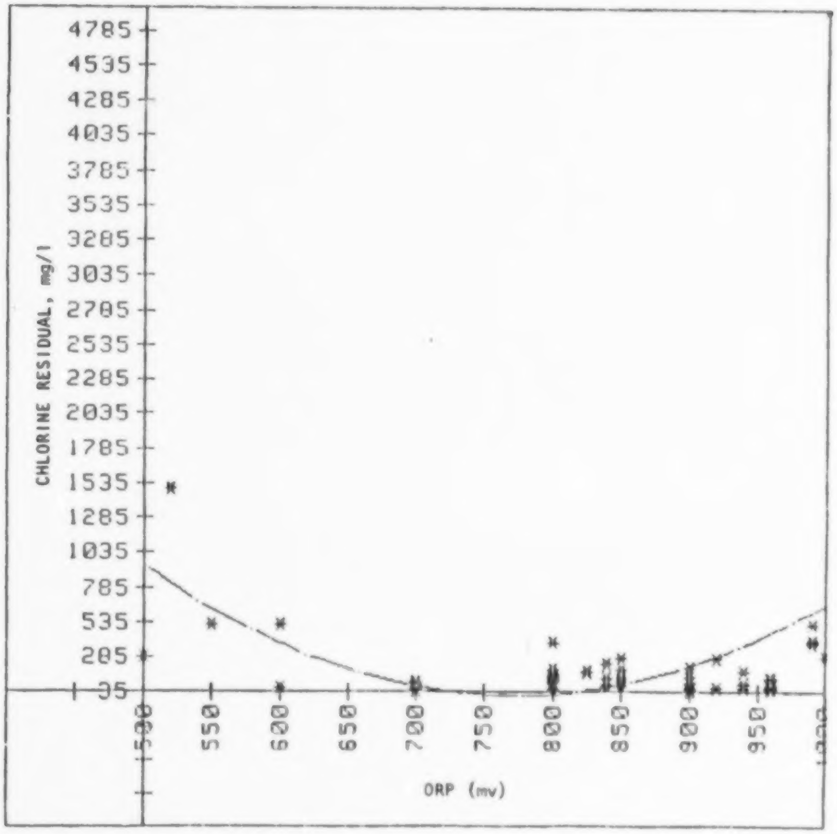


Figure 15. Plot of chlorine residual versus oxidation - reduction potential.

was due to the large concentrations of cyanide, phenol, thiocyanate, ammonia and other oxidizable material present in the coke plant wastewater.

System Description, Costs and Space Requirements

The data generated in the pilot scale study were evaluated for scale-up to full-size installations. For purposes of costing, two designs have been prepared. Design No. 1 was costed using a typical run from the pilot study which met BAT (non-priority pollutant) guidelines (Run No. 10). This run closely approximated the BPT ammonia standard, although the wastewater was significantly above BPT limits for phenol and cyanide-T as shown in Table 21.

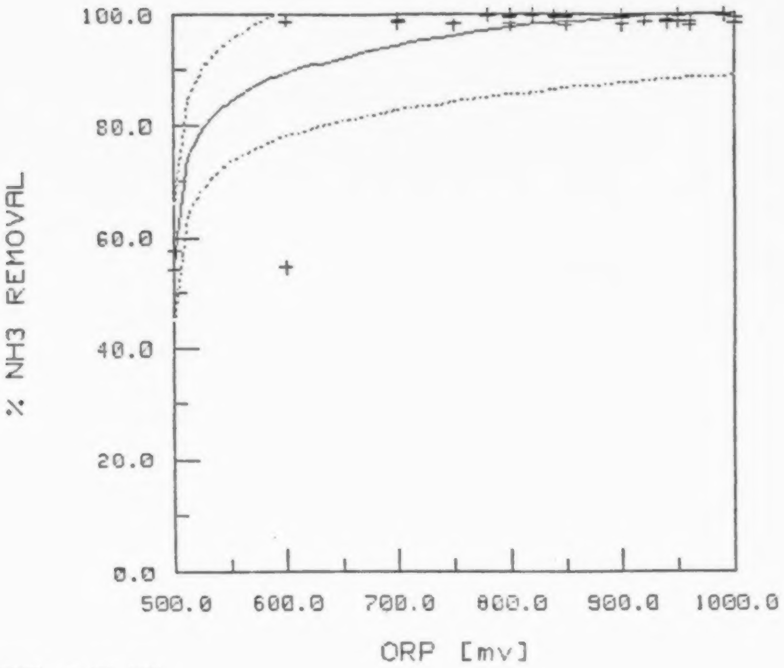
The results from the pilot alkaline chlorination testing determined that non-priority pollutant BAT guidelines could be achieved for runs operating at an ORP setting between 820 mv and 960 mv. From Figure 16 it can be seen that operation at an oxidation-reduction potential of greater than 820 mv consistently resulted in an ammonia removal of greater than 90 percent.

TABLE 21. PILOT STUDY AND EPA GUIDELINE DATA

Item	CN-T, mg/l	Phenol, mg/l	NH_3, mg/l	O&G, mg/l	SS, mg/l	S, mg/l	SCN, mg/l
Coke plt. eff. (pilot system average feed conc.)	85.2	142	506	54	103	46.7	273
BPT limits for coke plt. eff.[a]	29	2	123	15	49	-	-
BAT limits for coke plt. eff.[a]	0.33	0.27	13	13	27	0.4	200
Run No. 10-Inf.	267.5	68	106	-	65	24.8	300
-Eff.	I	0.1	2	-	7	<0.2	2

I: Denotes interference.
a. From Reference No. 1.

Design No. 2 has been prepared assuming the inlet wastewater pollutant parameters were at BPT levels. This results in a net reduction in chemical usage, since concentrations of influent parameters are lower than in Run No. 10.



```
INTERCEPT   = 35.103
SLOPE       = 17.117
Rsquared    = .719
CORRELATION= .848
```

Figure 16. Plot of percent ammonia removal versus ORP setting - alkaline chlorination testing.

Treatment of the coke plant wastewater on a full-scale would be a two-step process. In the first step the incoming wastewater pH would be elevated using caustic soda. Chlorine would be added and the contents mixed in-line, and fed to the cyanide treatment tank. Constant ORP and pH would be maintained by controllers and a tank mixer. After a design detention time of thirty minutes, the effluent would be pH adjusted and again blended with chlorine for ammonia removal. The contents would be mixed in-line prior to entering the ammonia treatment tank. The design detention time in this tank would be 6 minutes and the system would be equipped with pH and ORP controllers and a mixer to maintain constant conditions. Alarm systems for high concentrations of cyanogen chloride and nitrogen trichloride would also be provided. A schematic of the full-scale continuous alkaline chlorination treatment system is shown in Figure 17.

Several assumptions were used in preparing the cost estimates and these are listed below.

ASSUMPTIONS USED TO DEVELOP COST ESTIMATES FOR FULL-SCALE ALKALINE CHLORINATION SYSTEM

1. Chemical Costs (Bulk)
    - Caustic Soda (50%): \$1.46/3.785ℓ (\$1.46/gal.)
    - Sulfuric Acid (66° Be'): \$0.59/3.785ℓ (\$0.59/gal.)
    - Chlorine Gas:
        - Ton Cylinders: \$0.06/kg (\$.14/lb)
        - Tank Cars: \$0.03/kg (\$.07/lb)
2. Peak chlorine usage = 2 x average
3. Peak caustic and acid usage = 5 x average

Tables 22 and 23 summarize the design basis used for the cost estimates. Designs have been provided for flows of 379 m^3/day (0.1 mgd), 1,022 m^3/day (0.27 mgd) and 3,785 m^3/day (1.0 mgd).

Cost and Space Requirements

Using the design information developed in Tables 22 and 23, alkaline chlorination treatment costs were computed for each of the design flows. Costs for the system components were based on vendor quotations. The primary installed equipment costs include:

1. Reaction Tanks.
2. Mixers.
3. pH and ORP Controllers.
4. Chemical Stock Tanks.

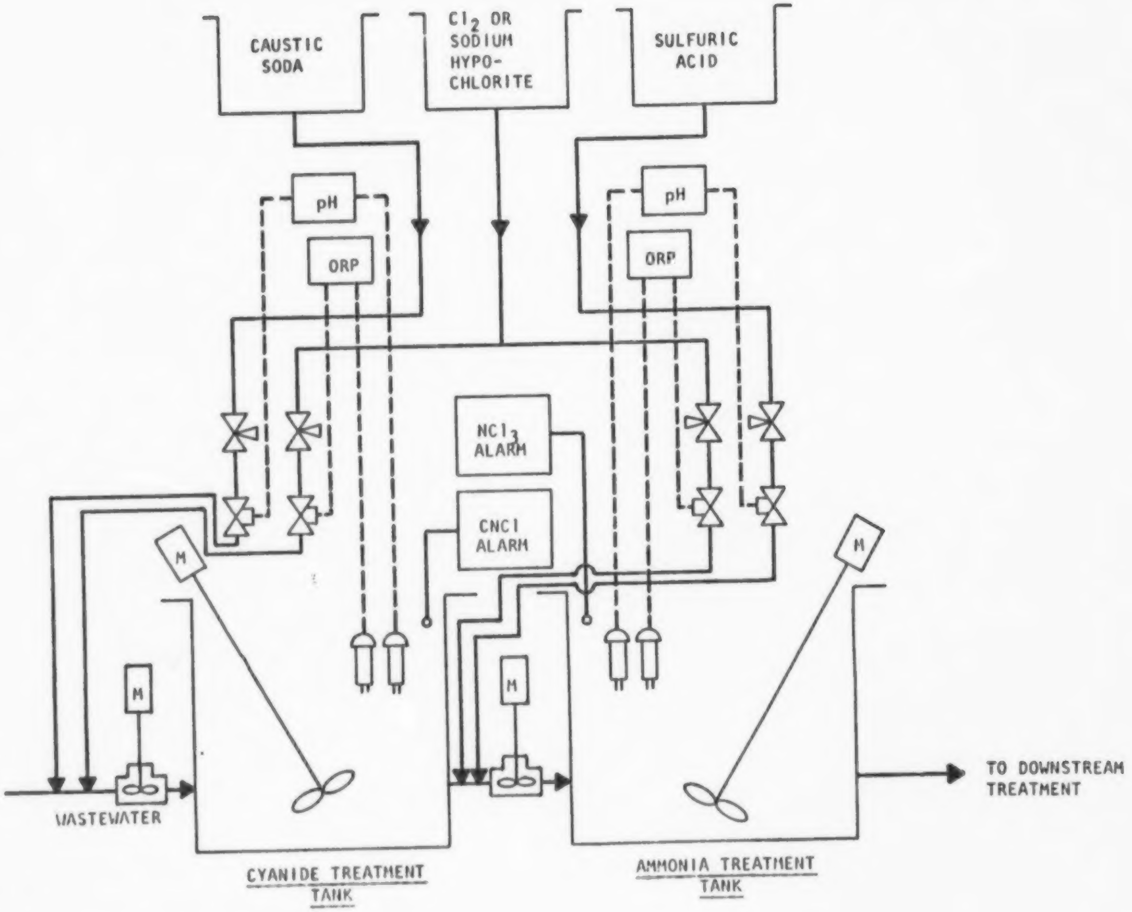

CAUSTIC SODA
Cl_2 OR SODIUM HYPO-CHLORITE
SULFURIC ACID
pH
ORP
pH
ORP
NCl_3 ALARM
CNCl ALARM
M
M
M
M
WASTEWATER
CYANIDE TREATMENT TANK
AMMONIA TREATMENT TANK
TO DOWNSTREAM TREATMENT

Figure 17. Schematic for full-scale continuous treatment of cyanide and ammonia.

TABLE 22. ALKALINE CHLORINATION DESIGN DATA - BASED ON RUN NO. 10

Type of Waste	ACTUAL COKE PLANT EFFLUENT (using Run No. 10 Influent)		
Design Flow, m^3/day (mgd)	379 (0.1)	1,022 (0.27)	3,785 (1.0)
Contact Time, min.			
cyanide removal tank	30	30	30
ammonia removal tank	6	6	6
Mixing Requirements (Mechanical)			
cyanide removal tank [min. G, m/sec/m, (ft/sec/ft)]	900 (900)	900 (900)	900 (900)
ammonia removal tank [min. G, m/sec/m, (ft/sec/ft)]	900 (900)	900 (900)	900 (900)
Chemical Requirements			
Caustic Soda (50%), liters/day (gal./day)	3,407 (900)	8,706 (2,300)	32,551 (8,600)
H_2SO_4, (66° Be'), liters/day (gal./day)	379 (100)	946 (250)	3,407 (900)
Chlorine Gas, kg/day (lb/day)	1,952 (4,300)	5,448 (12,000)	19,522 (43,000)
Chemical Stock Tank Design Storage			
Caustic Soda	7 Days	7 Days	7 Days
H_2SO_4	30 Days	30 Days	30 Days
Chlorine Gas	40 Days	15 Days	4 Days

TABLE 23. ALKALINE CHLORINATION DESIGN DATA - ASSUMING INLET WASTEWATER MEETS BPT GUIDELINES

Type of Waste	BPT FEEDWATER ASSUMED		
Design Flow, m^3/day (mgd)	379 (0.1)	1,022 (0.27)	3,785 (1.0)
Contact Time, min.			
cyanide removal tank	30	30	30
ammonia removal tank	6	6	6
Mixing Requirements (Mechanical)			
cyanide removal tank [min. G, m/sec/m, (ft/sec/ft)]	900 (900)	900 (900)	900 (900)
ammonia removal tank [min. G, m/sec/m, (ft/sec/ft)]	900 (900)	900 (900)	900 (900)
Chemical Requirements			
Caustic Soda (50%), liters/day (gal./day)	1,703 (450)	4,164 (1,100)	17,033 (4,500)
H_2SO_4, (66° Be'), liters/day (gal./day)	379 (100)	946 (250)	3,407 (850)
Chlorine Gas, kg/day (lb/day)	908 (2,000)	2,452 (5,400)	9,080 (20,000)
Chemical Stock Tank Design Storage			
Caustic Soda	7 Days	7 Days	7 Days
H_2SO_4	30 Days	30 Days	30 Days
Chlorine Gas	90 Days	30 Days	9 Days

5. Building
6. Associated Pumps, Valves, Piping and Controls
7. Cyanogen Chloride and Nitrogen Trichloride Alarm Systems
8. Chlorinators and Evaporators
9. Winterization (excluding exposed pipe insulation).

Tables 24 and 25 summarize the cost data for alkaline chlorination. The cost information in the tables assume an equalized, pressurized feed stream and chlorine gas usage. The costs are shown for major equipment components and the primary operating costs. In addition, the tables provide the expected total yearly cost for treatment in $/3,785 liters ($/1,000 gal.). Also shown in Tables 24 and 25 are the land requirements for each of the system designs. Sufficient space has been allowed between reaction tanks to allow for aisle ways and the performance of routine maintenance. There is no space allowance for a railroad siding, wastewater collection system or an equalization basin.

By comparing Tables 24 and 25, it can be seen, that applying the BAT scheme to a waste stream that meets BPT parameters results in about a 45 percent reduction in total yearly cost. This confirms previous discussion that the most cost effective approach to meeting the BAT coke plant guidelines with physical/chemical treatment would be to first optimize the pre-treatment system to reduce pollutant concentration to BPT levels.

DUAL MEDIA FILTRATION STUDY

Introduction

Dual media filtration tests were performed on the coke plant effluent as a polishing step from November, 1979 through January 1980. During November and December, filtration tests of alkaline chlorinated effluent were performed (See Figure 18). During January, filtration tests on alkaline chlorinated effluent dechlorinated with sodium bisulfite and pretreated with polymer were conducted (See Figure 19). The filtration media used in the tests consisted of 38 cm (15 in.) of Red Flint filter sand (effective size 0.47 mm) and 43 cm (17 in.) of anthracite coal (effective size 0.94 mm).

Data Collection and Results

Dual media filtration results for filtering the alkaline chlorinated effluent without polymer are summarized in Table 26. Filtration removed significant quantities of suspended solids (71% removal).

Table 27 shows the average, maximum and minimum influent and effluent characteristics when alkaline chlorinated coke plant wastewater was filtered with polymer as a coagulant aid. Overall removal of suspended solids (93% removal) was greatly improved by the addition of the polymer.

In addition to overall performance data, the effect of specific operating parameters was determined for each filter run. Since suspended solids

TABLE 24. ALKALINE CHLORINATION COST SUMMARY
BASED ON PILOT RUN NO. 10

Design Flow Rate, m³/day (mgd)	379 (0.1)	1,022 (0.27)	3,785 (1.0)
Capital Cost[a,b]			
Chemical Pumps	$ 4,000	$ 5,000	$ 6,000
Tankage	15,000	24,000	61,000
Controllers (pH & ORP)	16,000	16,000	16,000
Mixers	8,000	13,000	21,000
Electrical Panel	5,000	6,000	7,000
Alarm System	11,000	11,000	11,000
Chlorinators and Evaporators	30,000	45,000	$ 100,000
Delivered Equipment Total	$ 89,000	$ 120,000	$ 222,000
Equipment Installation	36,000	48,000	89,000
Installed Equipment Total	$125,000	$ 168,000	$ 311,000
Process Piping	38,000	50,000	93,000
Instrumentation	6,000	8,000	16,000
Capital Equipment Total	$169,000	$ 226,000	$ 420,000
Facilities & Fees	364,000	485,000	1,168,000
Capital Cost Total	$533,000	$ 711,000	$1,588,000
Operating Cost			
Electrical	$ 1,000	$ 2,000	$ 4,000
Operator	57,000	57,000	57,000
Maintenance Labor & Materials	9,000	11,000	21,000
Chemicals	611,000	1,586,000	5,865,000
Yearly Operating Subtotal	$678,000	$1,656,000	$5,947,000
Capital Amortization 20 yr life @ 7.125%	$50,000	$66,000	$148,000
Total Annualized Cost, $/yr[c]	$728,000	$1,722,000	$6,095,000
$/3,785ℓ ($/1,000 gal.)	$19.94	$17.47	$16.70
Land Requirement[d] m² (ft²)	139(1,500)	223(2,400)	465(5,000)

---

a. See Appendices C and D for basis of estimate. All prices are effective as of May 1, 1980.

b. Assumes a pressurized, equalized feed flow.

c. Annualized Cost = Operating Cost + Capital Amortization.

d. Exclusive of a railroad siding for chlorine, wastewater collection system and an equalization bain.

TABLE 25. ALKALINE CHLORINATION COST INFORMATION BASED ON COKE PLANT BPT EFFLUENT

Design Flow Rate, m^3/day (mgd)	379 (0.1)	1,022 (0.27)	3,785 (1.0)
Capital Cost[a,b]			
Chemical Pumps	$ 4,000	$ 5,000	$ 6,000
Tankage	10,000	18,000	43,000
Controllers (pH & ORP)	16,000	16,000	16,000
Mixers	8,000	13,000	21,000
Electrical Panel	5,000	6,000	7,000
Alarm System	11,000	11,000	11,000
Chlorinators and Evaporators	30,000	45,000	100,000
Delivered Equipment Total	$ 84,000	$114,000	$ 204,000
Equipment Installation	34,000	46,000	82,000
Installed Equipment Total	$118,000	$160,000	$ 286,000
Process Piping	35,000	48,000	86,000
Instrumentation	6,000	8,000	14,000
Capital Equipment Total	$159,000	$216,000	$ 386,000
Facilities & Fees	342,000	465,000	831,000
Capital Cost Total	$501,000	$681,000	$1,217,000
Operating Cost			
Electrical	$ 1,000	$ 2,000	$ 4,000
Operator	57,000	57,000	57,000
Maintenance Labor & Materials	9,000	11,000	21,000
Chemicals	312,000	778,000	3,092,000
Yearly Operating Subtotal	$379,000	$848,000	$3,174,000
Capital Amortization			
20 yr life @ 7.125%	$48,000	$65,000	$116,000
Total Annualized Cost, $/yr[c]	$427,000	$913,000	$3,290,000
$/3,785ℓ ($/1,000 gal.)	$11.70	$9.26	$9.01
Land Requirement[d]			
m^2 (ft^2)	139(1,500)	223(2,400)	465(5,000)

---

a. See Appendices C and D for basis of estimate. All prices are effective as of May 1, 1980.

b. Assumes a pressurized, equalized feed flow.

c. Annualized Cost = Operating Cost + Capital Amortization.

d. Exclusive of a railroad siding for chlorine, wastewater collection system and an equalization basin.

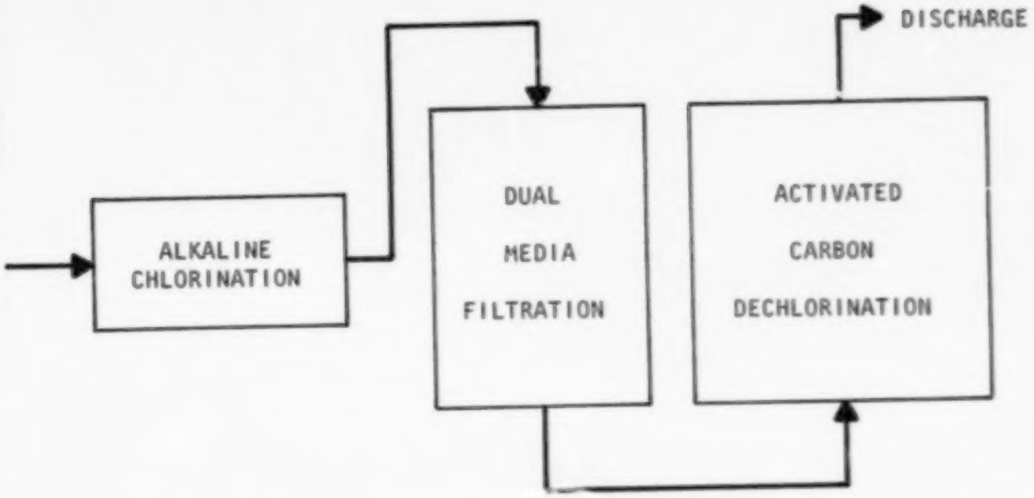

DISCHARGE
ALKALINE CHLORINATION
DUAL MEDIA FILTRATION
ACTIVATED CARBON DECHLORINATION

Figure 18. Dual media filtration of alkaline chlorinated coke plant effluent.

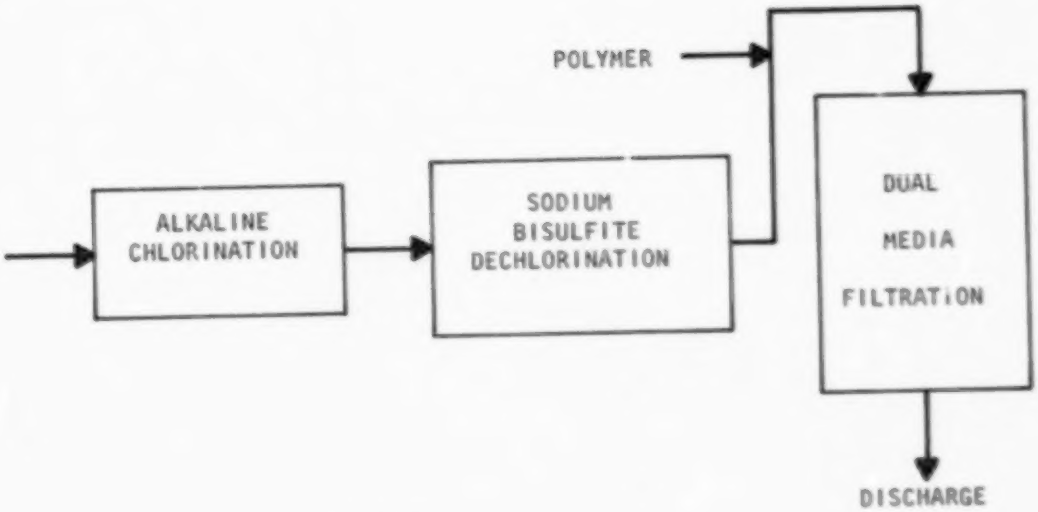

POLYMER
ALKALINE CHLORINATION
SODIUM BISULFITE DECHLORINATION
DUAL MEDIA FILTRATION
DISCHARGE

Figure 19. Filtration of coke plant effluent pretreated with polymer.

TABLE 26. DUAL MEDIA FILTRATION OF PRETREATED COKE PLANT EFFLUENT - INFLUENT VS EFFLUENT QUALITY

	SS mg/l
	Influent
Average	51
Maximum	139
Minimum	7
	Effluent
Average	11
Maximum	36
Minimum	2

TABLE 27. DUAL MEDIA FILTRATION OF PRETREATED COKE PLANT EFFLUENT WITH POLYMER ADDITION - INFLUENT VS EFFLUENT QUALITY

	SS mg/l
	Influent
Average	71
Maximum	152
Minimum	10
	Effluent
Average	3
Maximum	9
Minimum	1

removal is the most important measure of filter performance, this parameter was monitored during each run in addition to the filtration rate, headloss and run time.

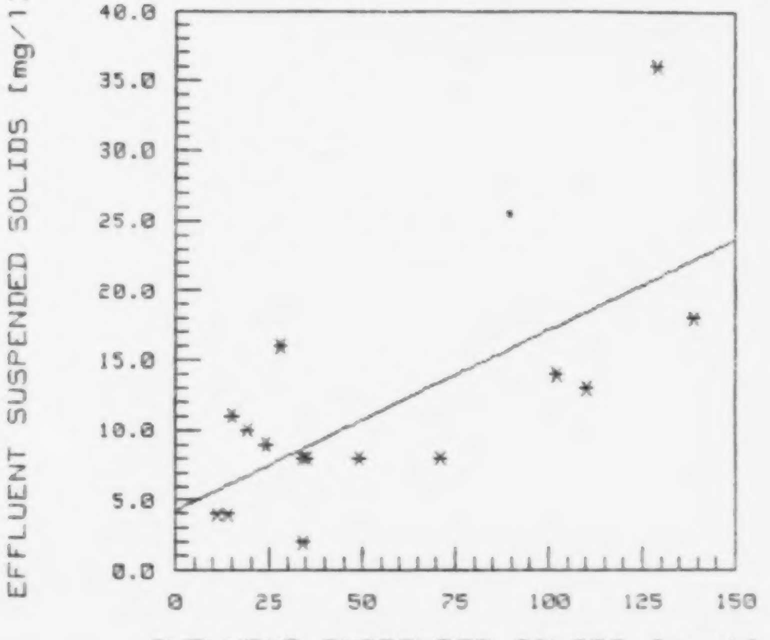
Accumulation of solids causes increasing pressure drop across the media. When sufficient solids have been deposited in the media, the headloss exceeds the design influent head and the filter must be backwashed to maintain the desired filtration rate. During any pilot study, the feed suspended solids varies from run to run and rarely equals the design conditions. Therefore, the most meaningful parameter of filter performance is the amount of solids trapped by the filter per unit area per unit headloss. This is usually reported in terms of kilograms suspended solids/m^2/m headloss (pounds suspended solids/ft^2/ft headloss).

Appendices B-7 and B-8 list all filter runs where complete information on filtration rate, headloss, run time, influent and effluent suspended solids, etc. were available. Also tabulated are the calculated solids loading capacities of each run. The tables separate runs in which alkaline chlorinated coke plant wastewater was filtered without polymer (Appendix B-7) from those with polymer. (Appendix B-8).

Alkaline Chlorinated Coke Plant Wastewater Filtered Without Polymer (Discussion)

The data tabulated in Appendix B-7 were used to characterize the filter operation for design purposes. From overall analysis of the alkaline chlorinated coke plant wastewater (without polymer addition) it has been determined that 51 mg/l suspended solids concentration is representative of this influent. By plotting individual filter run influent against effluent suspended solids it is possible to obtain additional insight into the feed characteristics. Notice in Figure 20 that filtration of this wastewater resulted in an average suspended solids removal efficiency of 71 percent. The graph illustrates that the particle size distribution was constant with varying influent solids content. This indicates that the filter removal efficiency is nearly constant for filtration without polymer. Table 28 summarizes the average solids loading for various filtration rates.

Of primary concern during this project was the alkaline chlorination of coke plant effluent. Therefore, the filter was shut down and backwashed each time a new alkaline chlorination test was initiated. Filtration rate was limited by the capacity of the alkaline chlorination equipment, and therefore the range of filter loading rates studied was limited. However, based on the filtration rates investigated, it can be seen that dual media filtration was an effective unit process for reducing suspended solids in the alkaline chlorination effluent.



INTERCEPT = 4.306
SLOPE = .120
Rsquared = .407
CORRELATION= .690

Figure 20. Dual media filter relationship of effluent to influent suspended solids for alkaline chlorinated coke plant wastewater filtered without polymer.

TABLE 28. SUMMARY OF DUAL MEDIA FILTER DATA FOR FILTRATION OF ALKALINE CHLORINATED COKE PLANT WASTEWATER WITHOUT POLYMER

	Filtration rate		Solids loading	
	ℓ/min/m^2	gpm/ft^2	kg SS/m^2/m H.L.	lb SS/ft^2/ft H.L.
Avg.	71.5	1.75	9.49	0.59
Max.	77.7	1.90	15.90	0.99
Min.	65.4	1.60	2.10	0.13

Note: lb SS/ft^2/ft H.L. x 16 = kg SS/m^2/m H.L.
gpm/ft^2 x 40.74 = ℓ/min/m^2

Alkaline Chlorinated Coke Plant Wastewater Filtered With Polymer (Discussion)

During this series of tests, the suspended solids content of the alkaline chlorinated coke plant wastewater averaged 71 mg/l. By plotting individual filter run influent suspended solids against effluent suspended solids, it is possible to obtain additional insight into the feed characteristics. Examining Figure 21 shows that filtration had an average suspended solids removal efficiency of 93%. The graph indicates that effluent quality is nearly independent of influent suspended solids concentration. As the influent suspended solids concentration increased, the polymer worked more effectively, resulting in higher solids capture and no significant change in effluent quality.

Table 29 summarizes the average solids loading for various filtration rates. The data presented in the table indicate that solids loadings at different flow rates are in the same range as for filtration without polymer (Table 28).

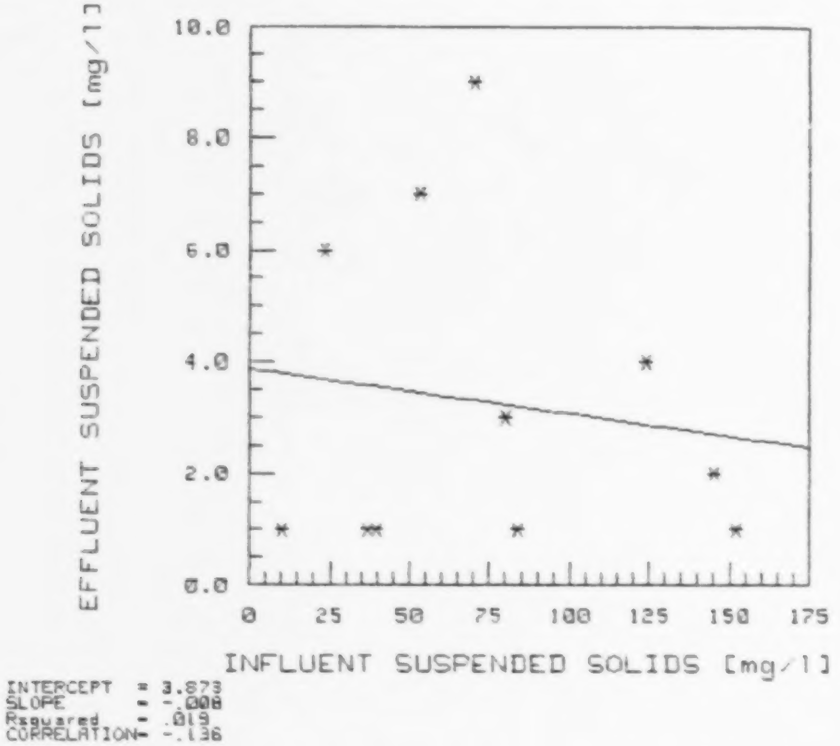


Figure 21. Dual media filter relationship of effluent to influent suspended solids for alkaline chlorinated coke plant wastewater filtered with polymer.

TABLE 29. SUMMARY OF DUAL MEDIA FILTER DATA FOR
FILTRATION OF ALKALINE CHLORINATED COKE PLANT WASTEWATER WITH POLYMER

	Filtration rate		Solids loading	
	ℓ/min/m^2	gpm/ft^2	kg SS/m^2/m H.L.	lb SS/ft^2/ft H.L.
Avg.	59.9	1.47	6.32	0.395
Max.	73.33	1.8	6.88	0.43
Min.	40.74	1.0	5.76	0.36

Note: lb SS/ft^2/ft H.L. x 16 = kg SS/m^2/m H.L.
gpm/ft^2 x 40.74 = ℓ/min/m^2

From Appendix B-8, it can be seen that solids loading was calculated for only 2 of the 12 filter runs. High salt content in the ΔP gauge prevented measurement of headloss through the filter media during this phase of the study. The solids loadings that were calculated are within the range of expected performance and compare with the filtration loadings for filtration without polymer.

It can be concluded that polymer addition prior to filtration of alkaline chlorinated coke plant wastewater greatly improved suspended solids capture. No flocculation of the wastewater was provided after addition of the polymer. However, adequate mixing prior to filtration was available by injecting the polymer on the upstream side of the dual media filter feed pump.

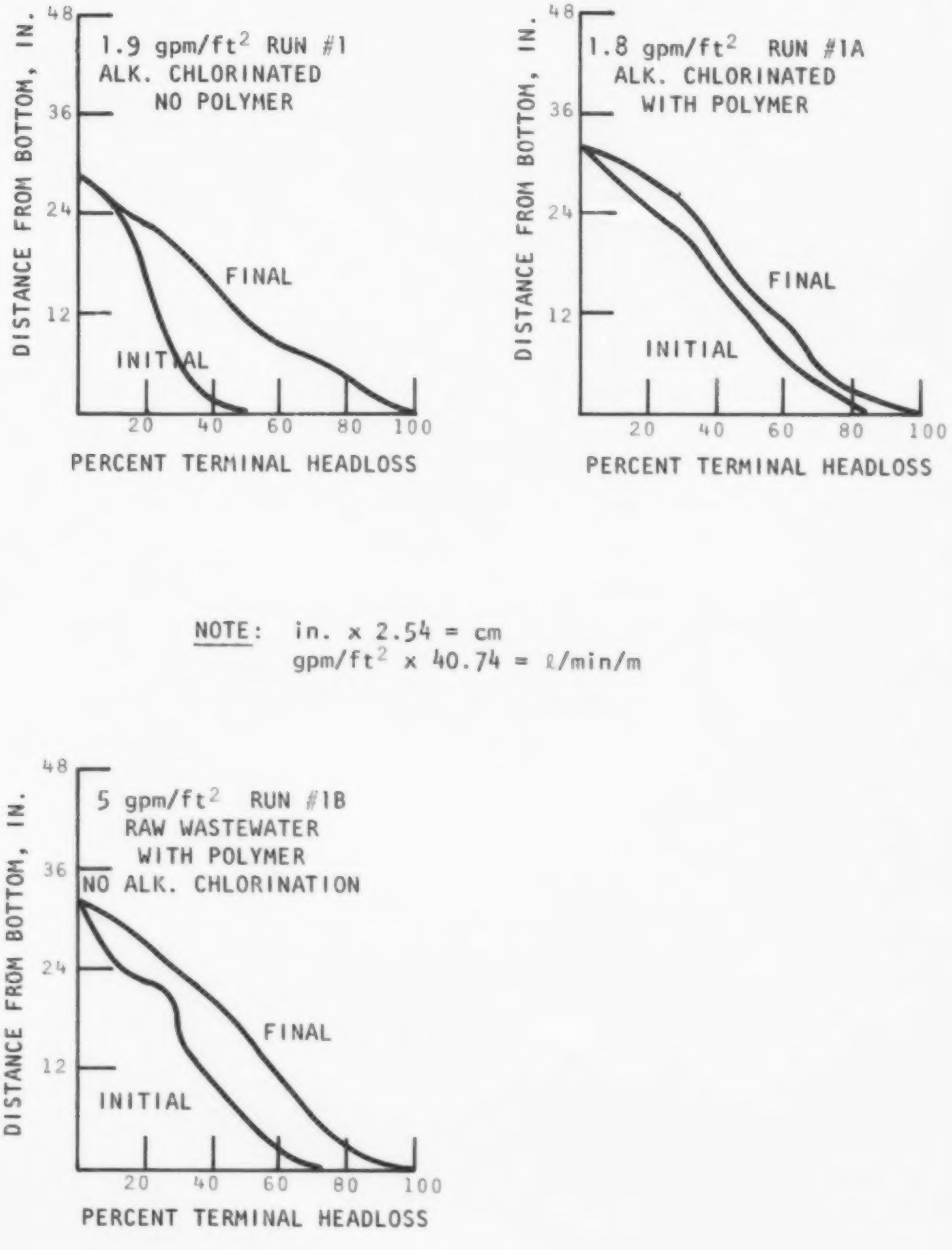
Headloss Profile

During each filter run, headloss profiles were taken to indicate how solids were deposited in the filter media. Typical headloss profiles are shown in Figure 22 for the filtration rates tested.

The modest slope of the profile line indicates the presence of in-depth filtration. A clearly defined sand/anthracite interface was not observed.

From the curves, it can be seen that the initial headloss curves are close to the final headloss curves because of the low final headloss value. The initial headloss curves follow the final headloss curves because the filter was backwashed before headloss increased to normal levels. Run time usually dictated backwash frequency, and not headloss.

Headloss is attributed to velocity losses and pluggage. At the low filtration rates of this study, suspended solids were deposited at a very slow rate. Therefore, the filter never approached terminal headloss (pluggage) before being backwashed for the next alkaline chlorination test.



NOTE: in. x 2.54 = cm
gpm/ft^2 x 40.74 = ℓ/min/m

Figure 22. Headloss profile with coke plant effluent.

Backwash

Throughout the pilot program the same backwash procedure was used. There was no observable deterioration of filter effectiveness as measured by the initial headloss or other performance parameters. A typical washout curve of suspended solids, shown in Figure 23, indicates adequate removal of solids when the wash rate was 530 ℓ/m^2/backwash (130 gal./ft^2/backwash).

Full-Scale Descriptions, Cost and Space Requirements

The data generated in the pilot scale study was analyzed for system scale-up to full-size installations.

Design Parameters--

From the above information and accepted filtration practice, parameters were selected for pressure filtration design. Table 30 summarizes the design basis used for the cost estimates. Pressure filtration is defined as having a terminal headloss of 7.6 meters (25 ft). Pressure filter design was based on constant head-constant rate.

Equipment Description-Pressure Filtration--

The pressure filter system for the 379 m^3/day (0.1 mgd) flow would consist of one vertical carbon steel 34 kg (75 lb) code vessel. The system would be provided with an upstream reservoir to accumulate incoming influent during the backwash cycle. The system would also be provided with an effluent tank that would serve as a source of backwash water.

The pressure filter systems for the 1,022 m^3/day (0.27 mgd) and 3,785 m^3/day (1.0 mgd) flow would consist of three vertical carbon steel 34 kg (75 lb) code vessels. During backwash the two pressure vessels in service would serve as the source of backwash water for the out of service vessel.

All systems would be capable of being backwashed first with water at 203 $\ell/min/m^2$ (5.0 gpm/ft^2) with simultaneous air scour at 1.5 $sm^3/min/m^2$ (5 scfm/ft^2) and then with water only at 610 $\ell/min/m^2$ (15.0 gpm/ft^2).

All systems would have automatically operated butterfly valves, stainless steel diffusers, carbon steel piping, air blower and one filter feed pump per vessel with one spare pump.

The filters would be filled with 30.5 cm (12 in.) of graded silica gravel, 38.1 cm (15 in.) of silica sand, and 43.2 cm (17 in.) of anthracite.

A front view cross section of a pressure filter is shown in Figure 24.

Equipment Costs--

Costs for filter components were based on vendor quotations, and from a recent edition of the Dodge Manual for Building Construction, Pricing and Scheduling (5). Equipment costs include:

1. Filter vessels and components.

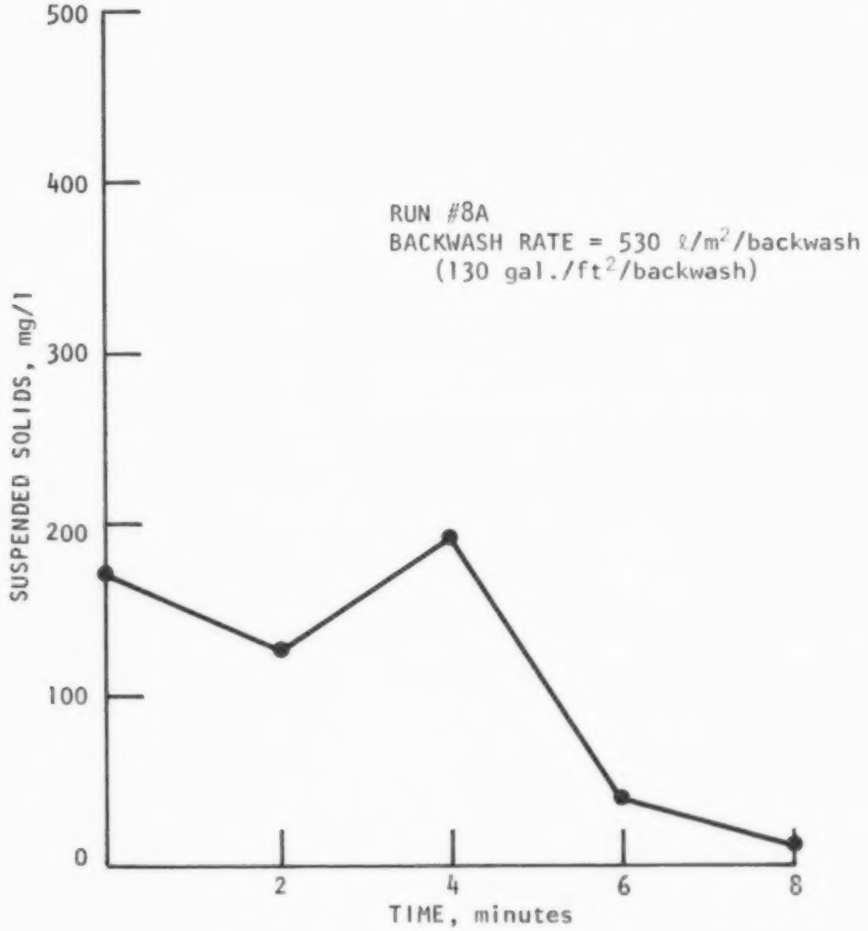


Figure 23. Typical suspended solids washout curve.

TABLE 30. DUAL MEDIA PRESSURE FILTER DESIGN DATA

Type of Waste	Coke Plant Effluent Without Polymer		
Design flow m^3/day (mgd)	379 (0.1)	1,022 (0.27)	3,785 (1.0)
Filter type	Pressure	Pressure	Pressure
Design influent mg/l SS	51	51	51
Design effluent mg/l SS	11	11	11
Filtration rate, ℓ/min/m^2 (gpm/ft^2)	163 (4.0)	163 (4.0)	163 (4.0)
Area required m^2 (ft^2)	1.62 (17.4)	4.36 (46.9)	16.2 (173.6)
Filter diameter m (ft)	1.45 (4.75)	1.37 (4.5)	2.67 (8.75)
Filter height m (ft)	2.44 (8.0)	2.44 (8.0)	2.44 (8.0)
Filter configuration	Vertical	Vertical	Vertical
Number of filters	1	3	3
Area per filter m^2 (ft^2)	1.64 (17.7)	1.48 (15.9)	5.59 (60.1)
Backwash usage %	1.8	1.8	1.8
Backwash cycle duration, min.	30	30	30
Filter cycle time, hr	35.5	35.5	35.5
Depth of anthracite, cm (in.)	43.2 (17)	43.2 (17)	43.2 (17)
Depth of silica sand, cm (in.)	38.1 (15)	38.1 (15)	38.1 (15)
Depth of gravel, cm (in.)	30.5 (12)	30.5 (12)	30.5 (12)

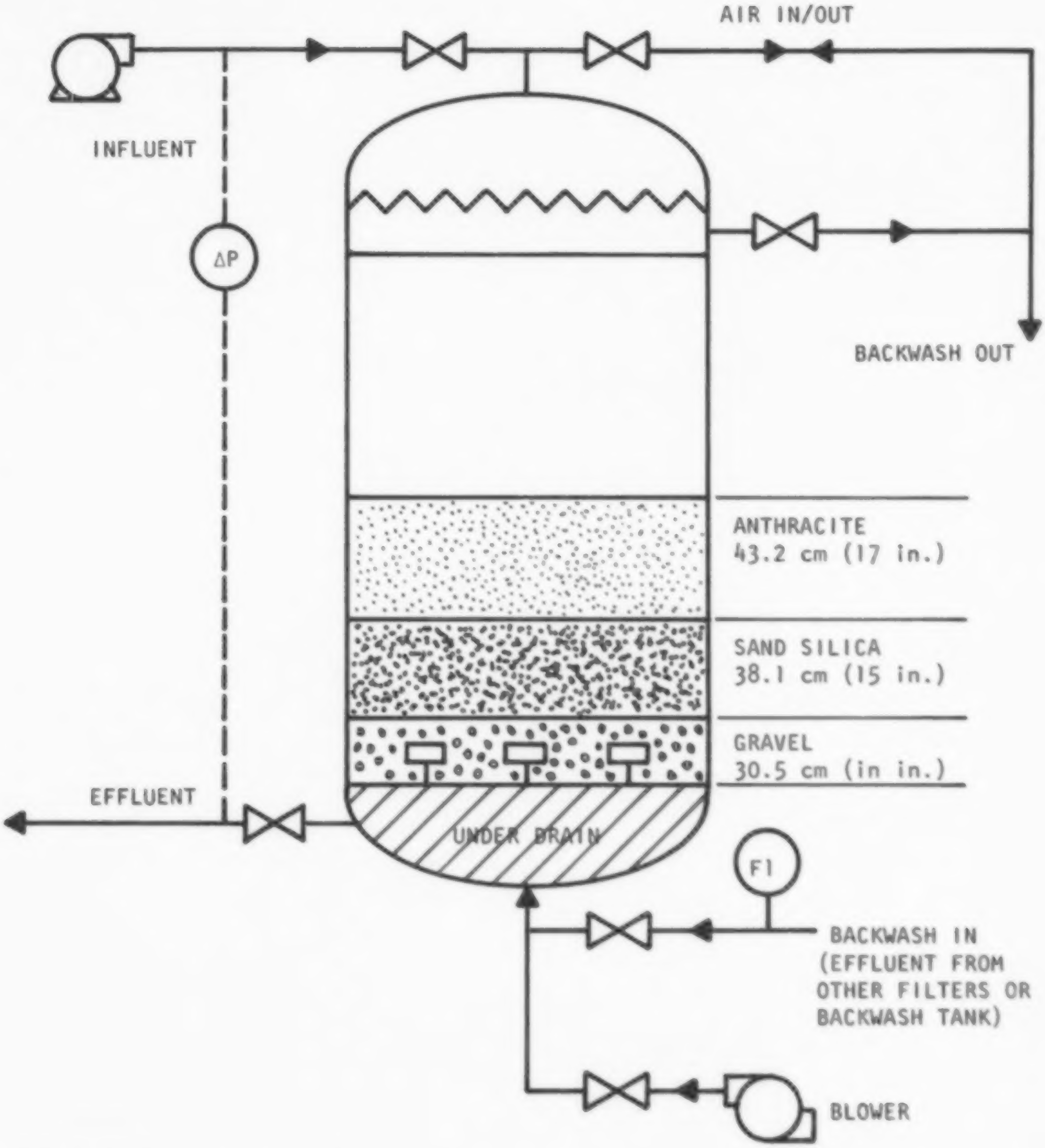

AIR IN/OUT
INFLUENT
ΔP
BACKWASH OUT
ANTHRACITE
43.2 cm (17 in.)
SAND SILICA
38.1 cm (15 in.)
GRAVEL
30.5 cm (in in.)
EFFLUENT
UNDER DRAIN
FI
BACKWASH IN
(EFFLUENT FROM
OTHER FILTERS OR
BACKWASH TANK)
BLOWER

Figure 24. Front view of vertical pressure filter.

2. Backwash reservoir where needed.
3. Valves, actuators and controls for automatic operation.
4. Media.
5. Pumps and motor control center.
6. Air blower for air scour.
7. Control console.
8. Interconnecting piping between filter vessels where needed.
9. Building.
10. Winterization (excluding exposed pipe insullation)

Annualized Costs--
Components of the annualized cost include power, operation labor, maintenance labor, maintenance material and amortization of capital. Items included in the analysis are discussed as follows:

Electrical--For all filters, the costs of operating the pumps and air scour blowers were based on the backwash frequency and the cycle duration. Electrical costs for pressure filtration include power costs for the feed pumps operating at the design flow, 24 hours per day. Power costs were assumed to be 3.0¢/KWH.

Operation Labor--Operation of the 379 m^3/day (0.1 mgd) and 1,022 m^3/day (0.27 mgd) systems was assumed to require 40 percent attention during the three shifts while operation of the 3,785 m^3/day (1.0 mgd) system was assumed to require 50 percent attention during the three shifts. The first shift operator was assumed to be skilled labor grade at $19,000 per year, while second and third shift operators would be unskilled at $16,000 per year.

Maintenance Labor--This item includes taking all filters out of service once per year for cleaning and inspection. Other costs would include routine replacement of components and general preventive maintenance.

Maintenance Material--Included are allowances for replacement parts and replacement of lost media. Material for maintenance is a function of total capital costs.

Capital Amortization--An equipment service life of twenty years, amortized at 7.125 percent per year was assumed.

Items Not Included--Examples of items not included in this analysis are - fringe benefits, supervision, overhead, laboratory support, insurance and administration expenses.

Cost comparisons are calculated on the basis of equivalent annual values which include both capital amortization and operating costs. Results shown in Table 31 are expressed as total annualized costs and costs per 3,785 liters (one thousand gallons) design flow.

Absolute Cost Consideration--
The cost estimates presented in Table 31 are internally consistent and

suitable for comparison purposes within the scope of this report. It should be realized that the costs are limited to items listed previously and do not represent the absolute value of total installed cost. The intent is to compare the various alternatives with detail not available in published cost curves.

Land Requirements--

Also tabulated in Table 31 are the space requirements for the three designs. For the 379 m^3/day (0.1 mgd) system, the filter, pumps and blower were located along one wall and the influent and the effluent tanks along the opposite wall. Adequate spacing is provided between filter, tanks and walls to permit easy access to interconnecting piping and valving. An aisle way is provided down the center of the building.

For the 1,022 m^3/day (0.27 mgd) and the 3,785 m^3/day (1.0 mgd) systems, the filters are located along one wall with the pumps and blower between the filters. A wide aisle way is provided in front of the filters for servicing.

Treatment Option With Polymer--

Field testing indicated that filtration without polymer provided adequate suspended solids removal that met BAT limits. However, the treatment was not as effective and consistent as filtration with polymer. If a higher quality effluent would be desired, a polymer feed system would be required. Field work indicated that a dosing rate of 3 mg/l was needed for significant improvement in effluent quality. As shown in Table 32, the annualized cost for treatment would be increased significantly, primarily due to the direct cost of the polymer and secondly, due to amortization of the chemical feed system.

RESULTS OF THE ACTIVATED CARBON STUDY

Introduction

Breakpoint chlorination was used to remove ammonia and other BAT parameters from the coke plant wastewater. The chlorine oxidizes ammonia in the wastewater to nitrogen gas and other harmless byproducts. However, chlorine residuals result from the breakpoint process. The use of activated carbon was investigated to determine its effectiveness as a dechlorinating agent. The carbon will convert any free chlorine residual to chlorides. It will also convert any mono- and dichloramines present to free nitrogen gas and chlorides. A second purpose for investigating activated carbon was to determine the efficiency of carbon for the removal of toxic pollutants.

The activated carbon used in this investigation was virgin granular bituminous type F 300 purchased from Calgon Corporation. The process train evaluated to treat the coke plant wastewater to BAT (non-priority pollutant) levels included alkaline chlorination, dual media filtration, and activated carbon.

TABLE 31. DUAL MEDIA FILTER COST SUMMARY - NO POLYMER

Design flow, m^3/day (mgd)	379 (0.1)	1,022 (0.27)	3,785 (1.0)
Capital Cost[a]			
Filter components	$ 14,000	$ 32,000	$ 69,000
Feed pumps	2,000	4,000	7,000
Upstream reservoir	2,000	-	-
Backwash pump & tank	3,000	-	-
Delivered Equipment Total	$ 21,000	$ 36,000	$ 76,000
Equipment installation	9,000	15,000	31,000
Installed Equipment Total	$ 30,000	$ 51,000	$107,000
Process piping	9,000	15,000	32,000
Instrumentation	2,000	3,000	5,000
Capital Equipment Total	$ 41,000	$ 69,000	$144,000
Facilities & Fees	88,000	149,000	311,000
Total Plant Cost	$129,000	$218,000	$455,000
Operating Cost			
Electrical	$ 1,000	$ 2,000	$ 5,000
Operators	20,000	20,000	25,000
Maintenance Labor & Materials	2,000	4,000	9,000
Yearly Operating Total	$ 23,000	$ 26,000	$ 39,000
Capital Amortization (20 yr life; 7.125%)	$ 12,000	$ 21,000	$ 44,000
Total Annualized Cost[b]	$ 35,000	$ 47,000	$ 83,000
$/3,785ℓ ($/1,000 gal.)	0.96	0.48	0.23
Land Requirement m^2 (acres)	70 (.017)	90 (0.022)	130 (.032)

a. See Appendices C and D for basis of estimates. All prices are effective as of May, 1980.

b. Annualized Cost = Operating Cost + Capital Amortization.

TABLE 32. DUAL MEDIA FILTER COST SUMMARY - WITH POLYMER

Design flow, m^3/day (mgd)	379 (0.1)	1,022 (0.27)	3,785 (1.0)
Capital Cost[a]			
Filter components	$ 14,000	$ 32,000	$ 69,000
Feed pumps	2,000	4,000	7,000
Upstream reservoir	2,000	-	-
Backwash pump & tank	3,000	-	-
Chemical feed system	4,000	5,000	5,000
Delivered Equipment Total	$ 25,000	$ 41,000	$ 81,000
Equipment installation	10,000	16,000	33,000
Installed Equipment Total	$ 35,000	$ 57,000	$114,000
Process piping	11,000	17,000	34,000
Instrumentation	2,000	3,000	6,000
Capital Equipment Total	$ 48,000	$ 77,000	$154,000
Facilities & Fees	105,000	166,000	332,000
Total Plant Cost	$153,000	$243,000	$486,000
Operating Cost			
Chemicals	$ 3,000	$ 8,000	$ 28,000
Electrical	1,000	2,000	5,000
Operators	20,000	20,000	25,000
Maintenance Labor & Materials	2,000	4,000	9,000
Yearly Operating Total	$ 26,000	$ 34,000	$ 67,000
Capital Amortization (20 yr life; 7.125%)	$ 15,000	$ 23,000	$ 46,000
Total Annualized Cost[b]	$ 41,000	$ 57,000	$113,000
\$/3,785ℓ (\$/1,000 gal.)	1.12	0.58	0.31
Land Requirement m^2 (acres)	80 (.020)	100 (.024)	140 (.034)

[a] See Appendices C and D for basis of estimate. All prices are effective as of May, 1980.

[b] Annualized Cost = Operating Cost + Capital Amortization.

Data Evaluation

This study utilized four carbon columns operated in the upflow, series mode. A total of 0.56 m^3(20 ft^3) of activated carbon was used in this test to provide a contact time of 2 hours at the average flow of 4.97 ℓ/m (1.3 gpm). Since the activated carbon was preceded by dual media filtration, operating the carbon columns in the down flow mode to trap suspended solids was unnecessary. Upflow series operation also has the advantage of reducing any problems associated with the production of nitrogen gas ($N_2\uparrow$) during dechlorination. Any gases formed or trapped in the bed are purged from the columns at the top outlets by the rising water. Appendix B-9 presents the data obtained during the study.

Currently, no BAT effluent guidelines have been proposed for residual chlorine in treated by-product cokemaking plant wastewater. Municipal effluent guidelines, however, usually limit total available chlorine concentration to 1-5 mg/l in wastewater discharged to receiving bodies. Table 33 lists other critical parameters pertinent to the coke plant discharge and their proposed limits to meet BAT (non-priority pollutant) requirements.

TABLE 33. PROPOSED BAT EFFLUENT REQUIREMENTS

Parameter	Effluent concentration limits
pH	6-9
Ammonia	13.4 mg/l
Cyanide-T	0.33 mg/l
Thiocyanate	200 mg/l
Phenol	0.27 mg/l
Sulfide	0.40 mg/l
Suspended Solids	27 mg/l
Oil & Grease	13 mg/l

The average influent chlorine concentration to the carbon system during the study was 63.6 mg/l and the average effluent chlorine concentration was 3.4 mg/l. A summary of chlorine removal data across the activated carbon column is presented in Table 34. The average removal rate of the chlorine residual was 95 percent with a range from 83.9-100 percent. Influent and effluent chlorine data have been plotted in Figure 25. As shown in the figure, influent chlorine concentration was somewhat variable, ranging from 21.3 mg/l to 145.0 mg/l, however, the effluent chlorine residual remained relatively constant. The lowest effluent chlorine residual observed was 2.6 mg/l. However, based on discussions with the vendor it is possible to design a system to meet a 1 mg/l chlorine effluent limitation based on the results of the pilot study.

The pilot plant study confirmed the bench scale tests performed with this

TABLE 34. CHLORINE REMOVAL ACROSS ACTIVATED CARBON BED

Date	Inf. Cl_2 conc., mg/l	Eff. Cl_2 conc., mg/l	% Removal
11/30/79	99.3	0	100
	99.3	3.5	96.5
	145.0	3.5	97.6
12/1/79	141	3.5	97.5
12/3/79	58	3.5	94.0
12/4/79	99.3	2.6	97.4
12/5/79	60.2	2.6	95.7
12/6/79	49.5	2.6	94.7
12/7/79	60.2	3.5	94.2
12/8/79	67.0	3.5	94.8
12/9/79	74.4	3.1	95.8
12/10/79	35.5	3.5	90.1
12/11/79	39.0	3.5	91.0
12/12/79	35.4	3.5	90.1
12/13/79	60.3	3.5	94.2
12/14/79	49.6	3.5	92.9
12/17/79	53.2	3.5	93.4
12/18/79	35.4	4.4	87.6
12/19/79	24.8	4.0	83.9
12/20/79	21.3	4.4	79.3

wastewater regarding the poor chlorine removal on the activated carbon surface. This poor removal performance is believed to be due, in part, to organic interferences present in the coke plant wastewater and incomplete carbon acclimation. This will be discussed in detail later in this section. Based on the pilot study findings and vendor experience, it was determined that about 10 grams of activated carbon would be required to remove 1 gram of chlorine. An allowance has been made in this figure to compensate for wastewater organic interferences.

As expected, the carbon column had little effect on suspended solids removal. The average influent suspended solids level of 12 mg/l was reduced to an average effluent suspended solids level of 9 mg/l. Except for one data

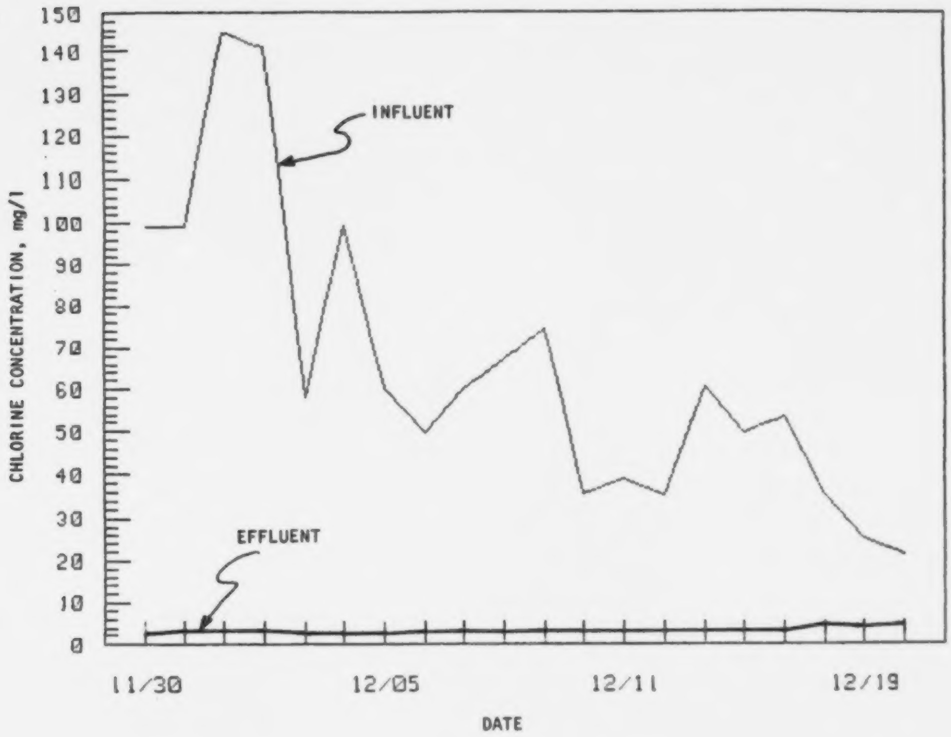


Figure 25. Influent and effluent chlorine concentrations observed during the activated carbon study.

point (36 mg/l), the influent suspended solids concentration ranged from 4-18 mg/l. This indicates that the proposed 27 mg/l suspended solids limit can be met by the dual media filter without any additional removal by the activated carbon. The one data point (36 mg/l) above the proposed limit occurred after a period of intensive alkaline chlorination testing at which time the dual media filter effluent may not have been representative.

The data in Appendix B-9 show that cyanide-T removal is possible using activated carbon. The influent cyanide-T concentration averaged 4.96 mg/l while the average effluent concentration was 2.88 mg/l. This represents an average cyanide-T removal of 42 percent. This is especially significant since the alkaline chlorination pilot study determined that cyanide-T would be the most difficult non-priority pollutant BAT parameter to meet.

Activated carbon was also effective in removing priority pollutants. This will be discussed in more detail in Section 7 of this report.

From Figure 26 it can be seen that the use of activated carbon resulted in a 61 percent removal of Total Organic Carbon (TOC). The average influent TOC concentration was 217 mg/l, and the effluent TOC concentration averaged

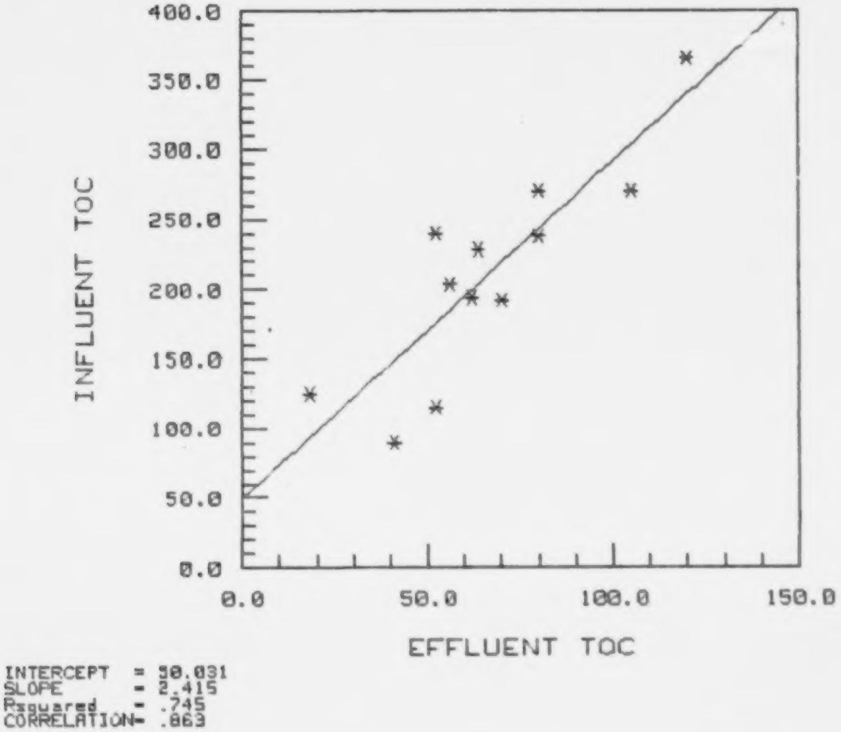


Figure 26. Influent versus effluent TOC for the activated carbon system.

84 mg/l. There is no proposed BAT effluent TOC limit for coke plants.

Activated carbon was also effective in removing phenol, as shown in Table 35. Influent concentrations of phenol were generally greater than the proposed limit of 0.27 mg/l, averaging 0.49 mg/l. With one exception, phenol concentrations in the effluent were below the proposed limit, with an average effluent concentration of 0.11 mg/l. The average phenol removal was 73 percent. Two effluent data points were not used in calculating the average, since they were greater than the influent phenol concentrations.

Full-Scale System Description and Design

The data generated by the pilot scale study were evaluated and used to develop cost estimates for full-scale activated carbon dechlorination treatment plants. Costs were estimated for three sizes of dechlorination systems, 378.5 m^3/day (0.1 mgd), 1,022 m^3/day (0.27 mgd), and 3,785 m^3/day (1.0 mgd). Table 36 summarizes the design data used as the basis for the cost estimates.

During the pilot scale study, cumulative flow and chlorine residual data were collected and tabulated, as shown in Appendix B-9. The average influent chlorine concentration of 63.6 mg/l was reduced to an average effluent

TABLE 35. PHENOL REMOVAL OBSERVED DURING PILOT STUDY

Date	Influent phenol, mg/l	Effluent phenol, mg/l	Percent removal
12/3/79	0.40	0.20	50.0
12/4/79	0.90	0.10	88.9
12/5/79	0.30	<0.01	>96.7
12/6/79	0.30	<0.01	>96.7
12/7/79	0.30	<0.01	>96.7
12/10/79	<0.01	<0.01	-
12/11/79	0.20	0.10	50.0
12/12/79	0.25	0.20	20.0
12/13/79	0.70	0.40	42.9
12/14/79	0.40	<0.01	>97.5
12/17/79	0.70	2.10	-[a]
12/18/79	0.60	0.10	83.3
12/19/79	0.60	1.10	-
12/20/79	1.2	0.2	83.3
		AVERAGE	73.3

[a] Start-up After Weekend Shutdown.

concentration of 3.4 mg/l, or 5.3 percent chlorine remaining. The water flowed through the four carbon columns in series with an average run contact time of 29 minutes per column. Even after this extended detention time, residual chlorine was found in the effluent. It is speculated that the incomplete chlorine removal resulted because of organic interferences present in the wastewater.

For full-scale design purposes, a contact time of 29 minutes and a chlorine loading of 0.1 g of Cl_2/g carbon were chosen as the most reasonable design criteria based on vendor estimating, pre-field lab investigations and actual field experience. Based on the results of the pilot study, the activated carbon vendor determined that an effluent chlorine concentration of <1 mg/l could be met by a full-scale carbon system. In discussions with the vendor, it was felt that because of the short term pilot study, the activated carbon was not completely acclimated. Previous research conducted by the vendor has determined that up to 2,000 bed volumes must be passed through the activated carbon to reach full acclimation. A fully acclimated carbon will contain a higher percentage of surface oxides, which would result in a lower effluent chlorine residual. Thus, although the pilot study effluent chlorine averaged about 3 mg/l, the vendor was confident that a 1 mg/l could be met and the full-scale system was designed accordingly. An allowance has been made in the design to compensate for organic interferences.

All proposed full-scale systems would utilize coal tar epoxy lined carbon steel adsorbers. A front view cross section of an activated carbon column is shown in Figure 27. All systems would have one extra adsorber and necessary valving to permit one adsorber to be off line for replacement of

TABLE 36. ACTIVATED CARBON DECHLORINATION SYSTEM DESCRIPTION AND OPERATING CHARACTERISTICS

System size, m^3/day (mgd)	378.5 (0.1)	1,022 (0.27)	3,785 (1.0)
Feed chlorine, (mg/l total available Cl_2)	63.6	63.6	63.6
Effluent chlorine, (mg/l total available Cl_2)	<1.0	<1.0	<1.0
System operation	Upflow	Upflow	Upflow
Number of adsorbers	2	5	5
Number of adsorbers on stream	1	4	4
Adsorber dimension, m (ft)(dia. x ht)	1.8x4.3 (6x14)	1.5x4.3 (5x14)	3.0x4.3 (10x14)
Carbon depth, m (ft)	2.9 (9.5)	2.8 (9.3)	2.6 (8.6)
Contact time, minutes	29	29	29
Carbon type	Bituminous	Bituminous	Bituminous
Carbon density, dry, kg/m^3 (lb/ft^3)	500 (31.2)	500 (31.2)	500 (31.2)
Carbon density, backwashed and drained, kg/m^3 (lb/ft^3)	424 (26.5)	424 (26.5)	424 (26.5)
Volume of carbon in initial fill, m^3 (ft^3)	7.7 (270)	20.6 (727)	76.5 (2,699)
Weight of carbon in initial fill, kg (lb)	3,829 (8,424)	10,310 (22,682)	38,277 (84,209)
Impurity loading, gm Cl_2/gm carbon	0.10	0.10	0.10
Carbon dosage, kg/1,000ℓ (lb/1,000 gal.)	0.64 (5.30)	0.64 (5.30)	0.64 (5.30)
Exhaustion rate, kg/day (lb/day)	241 (530)	650 (1,430)	2,410 (5,300)
Initial carbon fill price, $/kg ($/lb)	1.69 (.77)	1.69 (.77)	1.69 (.77)
Make-up carbon fill price, $/kg ($/lb)	1.69 (.77)	1.69 (.77)	1.69 (.77)

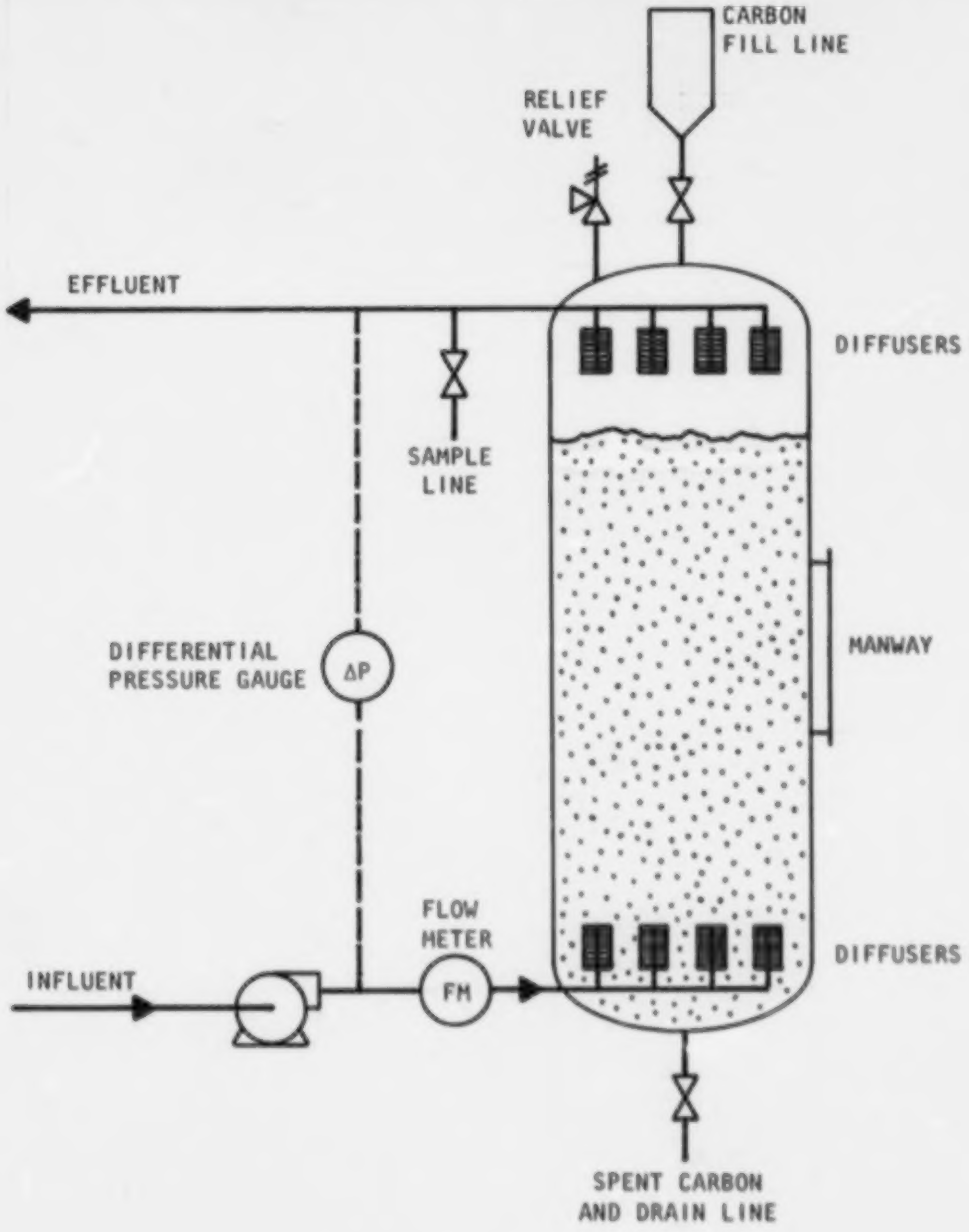

CARBON
FILL LINE
RELIEF
VALVE
EFFLUENT
DIFFUSERS
SAMPLE
LINE
DIFFERENTIAL
PRESSURE GAUGE
ΔP
MANWAY
FLOW
METER
FM
INFLUENT
DIFFUSERS
SPENT CARBON
AND DRAIN LINE

Figure 27. Front view of upflow activated carbon column.

spent carbon. The carbon would be replaced with virgin carbon when the effluent chlorine residual exceeded the maximum allowable concentration of 1 mg/l. The spent carbon could not be regenerated and would require disposal. This is because in the dechlorination process, the carbon surface is being oxygenated. High chlorine concentrations can convert the oxygenated carbon surface to CO↑ and CO_2↑. This will cause the carbon to be consumed. Even though all of the carbon is not consumed, the remaining spent material has reduced resistance to abrasion and less small pore volume and surface area due to oxidation, therefore making regeneration unattractive.

Concentrations of suspended solids in the wastewater would be reduced by upstream dual media filtration. This is necessary because carbon dechlorination requires an upflow operating mode and is not designed for suspended solids removal.

The full-scale adsorbers would operate in parallel at an approximate flow rate of 106 $l/min/m^2$ (2.6 gpm/ft^2). This is approximately double the flow rate used in the pilot system, however, the flow to the pilot unit carbon columns was limited by upstream processes. The flow rate selected by the vendor is well within accepted practice. The adsorbers would be designed to provide for 50 percent bed expansion during backwashing.

Table 37 presents the cost estimates for the proposed systems. The capital costs of the activated carbon systems include the adsorption system and a virgin carbon storage system. Installation costs are included in the capital costs. The capital cost of the adsorption systems include pumps, tanks, blow cases, adsorbers, flow control, piping, electrical work, foundations, winterization, the initial carbon fill, and indirect costs. The virgin carbon storage systems are designed to hold a 30 day supply.

RESULTS OF SODIUM BISULFITE DECHLORINATION

Introduction

Residual chlorine from the alkaline chlorination process may be removed by the addition of sodium bisulfite. The objective of these tests was to investigate the chlorine removal efficiency of sodium bisulfite and to obtain experimental design data. Sodium bisulfite ($NaHSO_3$) was purchased in dry form [22.7 kg (50 lb) bags] and mixed into a 40 mg/ml solution for addition into the wastewater. The treatment train included alkaline chlorination, dechlorination with sodium bisulfite, polymer addition, and dual media filtration.

Data Evaluation

After alkaline chlorination, the by-product cokemaking wastewater flowed through a 227 liter (60 gallon) mix tank. Here, sodium bisulfite solution and polymer were added and mixed. The detention time for mixing was 30 minutes at a 7.6 ℓ/min (2 gpm) flow rate. Polymer was added at a dose rate

TABLE 37. ACTIVATED CARBON DECHLORINATION SYSTEM COST ESTIMATES

System size, m^3/day (mgd)	378.5 (0.1)	1,022 (0.27)	3,785 (1.0)
Capital Cost[a]			
Adsorption system	$113,000	$ 202,000	$ 449,000
Carbon storage system[b]	78,000	154,000	337,000
Capital Equipment Total	$191,000	$ 356,000	$ 786,000
Facilities & Fees	410,000	766,000	1,691,000
Total Plant Cost	$601,000	$1,122,000	$2,477,000
Annualized Costs, $/year[c]			
Operator[d]	$ 12,000	$ 12,000	$ 16,000
Carbon make-up[e]	149,000	402,000	1,490,000
Maintenance[f]	10,000	18,000	39,000
Amortization of capital[g]	57,000	107,000	236,000
Total Annualized Cost	$228,000	$ 539,000	$1,781,000
$/3,785ℓ ($/1,000 gal.)	6.24	5.47	4.88
Land Requirement m^2 (acres)	106 (.026)	177 (.043)	367 (.090)

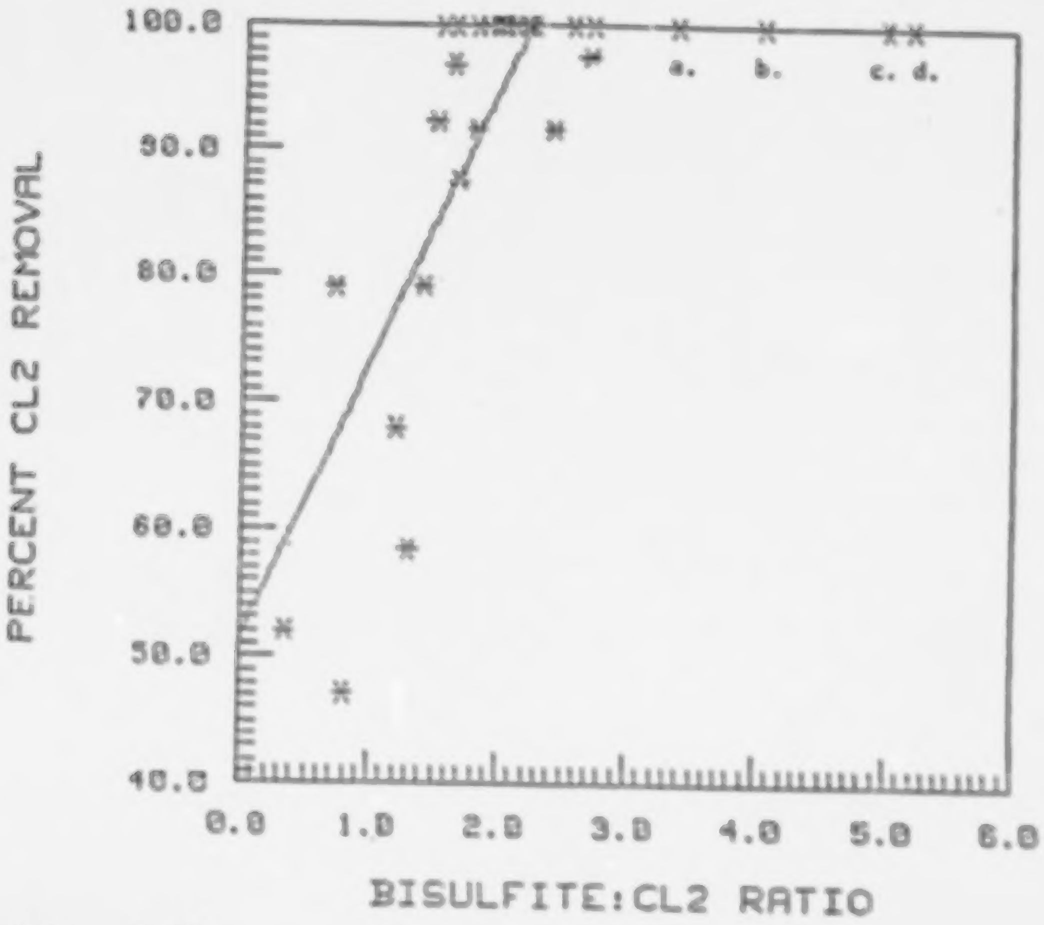
a. See Appendices C and D for basis of estimate.
b. Storage for 30 day supply.
c. Annualized Cost = Operating Cost + Capital Amortization
d. Unskilled at $16,000/year rate.
e. $1.60/kg ($0.77/lb).
f. 5% per year of capital equipment cost.
g. 20 year service life, 7.125% interest.

of approximately 3 mg/l to enhance filtration, which is discussed in a previous section of this report.

The sodium bisulfite experimental results are presented in Appendix B-10 and summarized in Table 38. From the data shown in Table 38, it is apparent that 100 percent of the residual chlorine can be removed by sodium bisulfite dechlorination. A plot of bisulfite:chlorine ratio and percent chlorine removal (Figure 28), shows that 100 percent of the chlorine can be removed at a bisulfite:chlorine ratio of 2:1. The figure, developed by computer, shows that chlorine removal is a function of the bisulfite to chlorine ratio. This is reflected in the high correlation factor (0.787). Note that all available chlorine is virtually destroyed whenever the bisulfite:chlorine ratio is 2:1 or greater. Earlier bench scale tests in the laboratory showed that 1.8 mg of bisulfite was required to remove 1.0 mg of chlorine. At pilot scale bisulfite:chlorine ratios of 1.8:1, one test showed 100 percent chlorine removal, and one test showed 91.7 percent

TABLE 38. SODIUM BISULFITE EXPERIMENTAL RESULTS SUMMARY

Run No.	Bisulfite:Cl_2 ratio	Influent Cl_2 residual mg/l	Effluent Cl_2 residual mg/l	Cl_2 Removal %
1	1.67:1	113.45	14.18	87.5
	0.71:1	269.0	56.00	79.1
2	1.87:1	198.2	0	100
	2.18:1	170.0	0	100
	2.00:1	184.3	0	100
3	1.49:1	184.3	14.18	92.3
	1.62:1	170.16	5.32	96.9
4	2.55:1	140.6	0	100
	2.02:1	177.6	0	100
	3.37:1	106.5	0	100
	4.05:1	88.6	0	100
5	1.98:1	141.6	0	100
	1.97:1	141.8	0	100
	1.64:1	141.8	0	100
	2.2:1	141.6	0	100
	2.7:1	85.0	0	100
6	1.8:1	85.0	0	100
	2.4:1	85.1	7.09	91.7
7	1.8:1	85.1	7.09	91.7
	0.8:1	201.36	106.35	47.2
	0.35:1	443.0	212.7	52.0
	1.2:1	127.62	40.8	68.0
8	5.2:1	70.9	0	100
	5.0:1	74.5	0	100
	1.3:1	290.7	120.5	58.5
	2.68:1	141.8	3.5	97.5
	1.4:1	273.0	56.7	79.2
	2.23:1	170.2	0	100
9	1.53:1	225.2	0	100
	1.94:1	198.5	0	100
	2.08:1	185.0	0	100



INTERCEPT - 51.588
SLOPE - 21.808
R SQUARED - .619
CORRELATION - .787

Note: Points a, b, c and d are not included in least squares fit due to skewness introduced by their inclusion. Literature indicates that Bisulfite:Cl_2 ratios greater than 2.5 nearly always yield 100% Cl_2 removal.

Figure 28. Plot of bisulfite:Cl_2 ratio vs. percent Cl_2 removal.

removal. To insure complete chlorine removal, a bisulfite:chlorine ratio of 2:1 should be used for design purposes.

Inspection of Appendix B-10 shows that pH was reduced slightly by the sodium bisulfite dechlorination process. The pH reduction ranged from 0.2-0.8 pH units, with most reduction being approximately 0.5 pH units. The pH depression was caused by formation of hydrochloric acid which is a by-product of the chlorine reduction step.

System Description, Sodium Bisulfite Dechlorination

The data generated from the pilot scale study were evaluated and used to design full scale systems for cost estimation purposes. Three sizes of full scale dechlorination systems were developed: 378 m^3/day (0.1 mgd), 1,022 m^3/day (0.27 mgd), and 3,785 m^3/day (1.0 mgd). Table 39 summarizes the design basis used for the cost estimates. Figure 29 shows a typical schematic of the equipment selected for the dechlorination systems estimated. A 2:1 design ratio of sodium bisulfite to chlorine ($NaHSO_3:Cl_2$) was selected on the basis of the pilot study. The dechlorination treatment tank was sized with a 30 minute detention time to allow ample time for chlorine reduction of both the free and combined residual. From the pilot study, the average chlorine residual of 174 mg/l was used to establish the daily chemical requirement. This concentration was generally higher than the chlorine residual observed in the feedwater to the activated carbon system. However, it must be remembered that the sodium bisulfite system directly followed the alkaline chlorination process; whereas, in the activated carbon treatment train, the alkaline chlorinated effluent was neutralized, and passed through a dual media filter prior to dechlorination on the carbon. Chlorine in water degrades rapidly and thus, the chlorine feedwater to the activated carbon system was consistently lower than the feedwater to the sodium bisulfite dechlorination tank.

In the full scale system, the wastewater from the alkaline chlorination system would be pumped to the dechlorination treatment tank where sodium bisulfite would be added as a solution. A proportional ORP controller would assure that constant ORP was maintained by controlling the chemical pump output rate. After being mixed for 30 minutes in the treatment tank, the dechlorinated wastewater would flow by gravity to the sewer, if acceptable for discharge, or to a downstream process for further treatment.

In all of the designs, sodium bisulfite solution would be prepared by emptying 45 kg (100 lb) bags into the day tanks and mixed with water once per day. The chemical storage tanks were sized on the basis of average chlorine residual, while the chemical pumps were sized for 2 times average chlorine residual. During periods of above average chlorine residual, more frequent refilling or the use of more concentrated sodium bisulfite solution may be required. Dry feeders were not considered due to the tendency for sodium bisulfite to form lumps if not properly stored.

Cost and Space Requirements--

Using the design information developed in Table 39, sodium bisulfite

TABLE 39. SODIUM BISULFITE DECHLORINATION DESIGN DATA

Type of Waste	Alkaline Chlorinated Coke Plant Wastewater		
Design flow, m^3/day (mgd)	378.5 (0.1)	1,022 (0.27)	3,785 (1.0)
Contact time, min.	30	30	30
Reaction Tank Volume, ℓ (gal.)	7,884 (2,083)	21,290 (5,625)	78,853 (20,833)
Design influent chlorine residual, mg/l	174	174	174
Design effluent chlorine residual, mg/l	<1	<1	<1
Design $NaHSO_3$:Cl_2 Ratio	2:1	2:1	2:1
Chemical Requirements			
Dry sodium meta-bisulfite, 97% purity kg/day (lb/day)	136 (300)	367 (810)	1,359 (3,000)
Day tank size, ℓ (gal.)[a]	2,271 (600)	6,132 (1,620)	22,710 (6,000)
Chemical Storage Requirements			
Dry pallet storage area for 30 days supply - m^2(ft^2)[b]	17.8 (192)	49.4 (520)	89.3 (960)

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a. Size based on 0.06 kg/ℓ (.5 lb/gal.) solution.
b. Stack pallets 2 layers high.

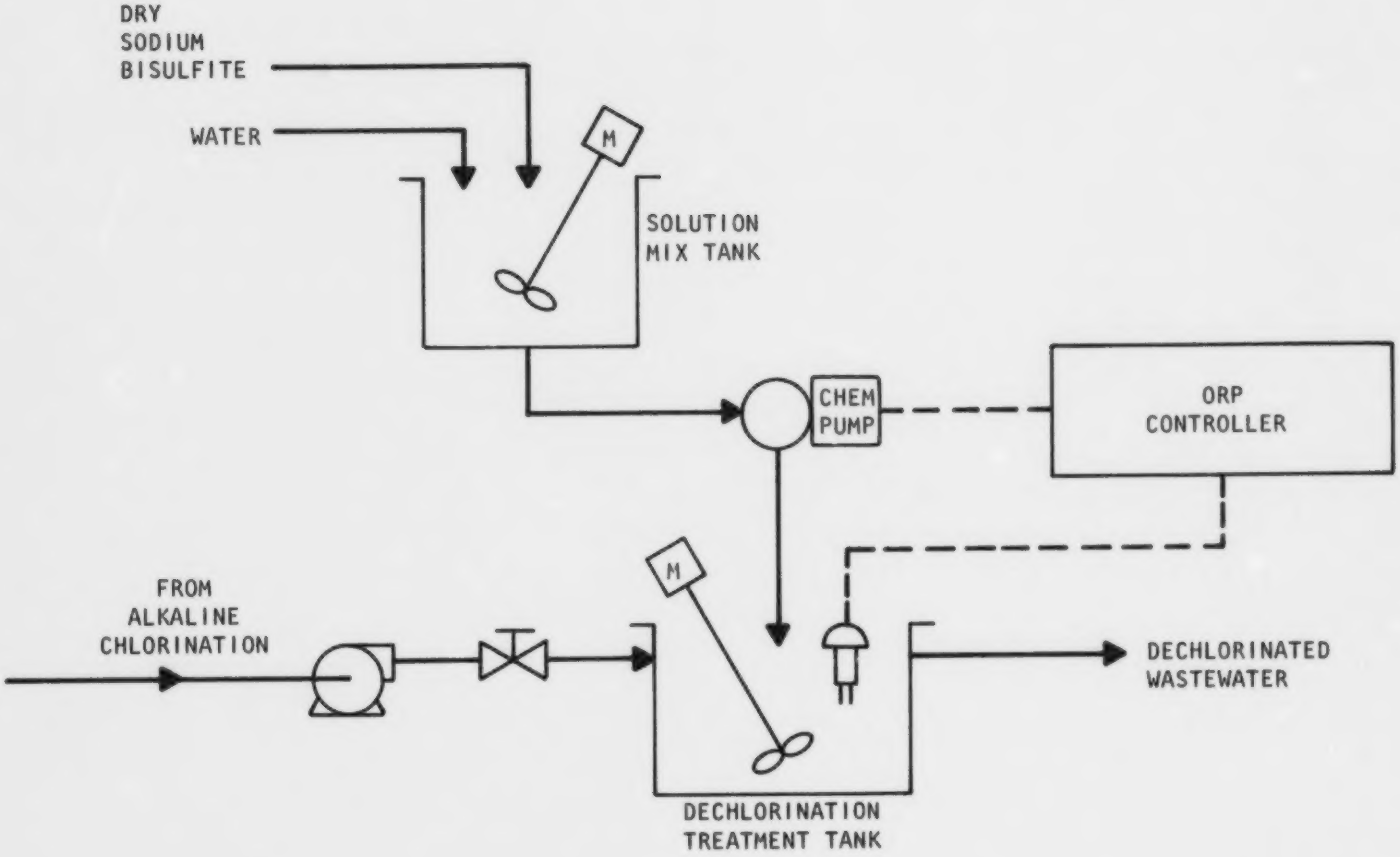

DRY
SODIUM
BISULFITE
WATER
M
SOLUTION
MIX TANK
CHEM
PUMP
ORP
CONTROLLER
FROM
ALKALINE
CHLORINATION
M
DECHLORINATED
WASTEWATER
DECHLORINATION
TREATMENT TANK

Figure 29. Schematic diagram for full scale dechlorination system using sodium bisulfite.

dechlorination costs were computed. Costs for the system components and operating costs were based on vendor quotations, catalog data, building cost analysis manuals, and the assumptions listed below.

ASSUMPTIONS USED TO DEVELOP COSTS FOR SODIUM BISULFITE DECHLORINATION

1. Design flow: 378.5 m^3/day (0.1 mgd)
   1,022 m^3/day (0.27 mgd)
   3,785 m^3/day (1.0 mgd)

2. Chemical costs, per bag: $18.25/45.3 kg (100 lb).

3. Design chlorine residual: average concentration - 174 mg/l

The primary equipment costs include:

1. Reaction Tanks.
2. Mixers.
3. ORP Controller.
4. Chemical Stock Tanks.
5. Associated Pumps, Valves, and Piping.
6. Electrical Controls.
7. Building.
8. Winterization (excluding external pipe insullation)

Table 40 summarizes the cost data for sodium bisulfite dechlorination. The costs shown are for major equipment components and primary operating costs. In addition, the table provides the estimated total yearly cost for treatment and the cost per 3,785 liters (1,000 gal.).

Annualized Cost--Components of the annualized cost include power, operation labor, maintenance labor, materials, chemicals, and amortization of capital. Items included in the analysis are discussed as follows.

Electrical--The power cost includes the costs for operating the feed pump, chemical pump, mixer, and instrumentation. Power cost was assumed to be 3.0¢/KWH.

Operating Labor--Operation of the 379 m^3/day (0.1 mgd) and 1,022 m^3/day (0.27 mgd) systems was assumed to require 40 percent attention during the three shifts while operation of the 3,785 m^3/day (1.0 mgd) system was assumed to require 50 percent attention during the three shifts. The first shift operator was assumed to be skilled labor grade at $19,000 per year, while second and third shift operators would be unskilled at $16,000 per year.

TABLE 40. SODIUM BISULFITE DECHLORINATION COST SUMMARY

Design flow, m^3/day (mgd)	378.5 (0.1)	1,022 (0.27)	3,785 (1.0)
Capital Cost[a]			
Reaction tanks	$ 3,000	$ 5,000	$ 10,000
Mixers	3,000	4,000	6,000
Feed pump & spare	2,000	4,000	6,000
Chemical pump	2,000	3,000	4,000
Chemical tanks	2,000	3,000	5,000
ORP controller	3,000	3,000	3,000
Control panel	3,000	3,000	4,000
Conveyor for chemicals	-	2,000	2,000
Access platforms	2,000	2,000	3,000
Delivered Equipment Total	$ 20,000	$ 29,000	$ 43,000
Equipment Installation	8,000	12,000	17,000
Installed Equipment Total	$ 28,000	$ 41,000	$ 60,000
Process Piping	8,000	12,000	18,000
Instrumentation	1,000	2,000	3,000
Capital Equipment Total	$ 37,000	$ 55,000	$ 81,000
Facilities & Fees	80,000	119,000	174,000
Capital Cost Total	$117,000	$174,000	$255,000
Operating Cost			
Electrical	$ 1,000	$ 3,000	$ 9,000
Operator	20,000	20,000	25,000
Maintenance Labor & Materials	2,000	3,000	4,000
Chemicals	20,000	54,000	200,000
Yearly Operating Subtotal	$ 43,000	$ 80,000	$238,000
Capital Amortization (20 yr life @ 7.125%)	$ 11,000	$ 17,000	$ 24,000
Total Annualized Cost ($/yr)[b]	$ 54,000	$ 97,000	$262,000
$/3,785 ℓ ($/1,000 gal.)	1.48	0.98	0.72
Land Requirement m^2 (acres)	35 (.009)	60 (.015)	110 (.027)

a. See Appendices C and D for basis of estimate. All prices are effective as of May, 1980.

b. Annualized Cost = Operating Cost + Capital Amortization.

Maintenance Labor--This item would include routine replacement of components and general preventative maintenance.

Maintenance Material--This item provides an allowance for replacement parts as required.

Chemicals--This item represents the cost of the sodium meta-bisulfite required in the dechlorination process.

Capital Amortization--An equipment service life of twenty years, amortized at 7.125 percent per year was assumed.

Items Not Included--Examples of items not included in this analysis are fringe benefits, supervision, overhead, laboratory support, insurance and administration expenses.

Land Requirements--Also tabulated in Table 40 are the space requirements for the three designs. Sufficient space has been allowed for aisleways and for the performance of routine maintenance.

A cost estimate was also prepared for a lower concentration chlorine feedwater. If an influent chlorine concentration of 63.6 mg/l is assumed (which is comparable to the design concentration used for activated carbon), the following costs would be realized.

Capital Costs--The capital costs are based on system feedwater and as such, would be identical to those listed in Table 40.

Flow	Capital Cost ($)
378.5 m^3/day (0.1 mgd)	117,000
1,022 m^3/day (0.27 mgd)	174,000
3,785 m^3/day (1.0 mgd)	255,000

Operating Costs--The operating cost is proportional to the chlorine concentration since chemical usage increases with increasing influent chlorine. For a feedwater chlorine concentration of 63.6 mg/l, the operating cost would be:

Flow	Operating Cost ($/yr)
378.5 m^3/day (0.1 mgd)	30,000
1,022 m^3/day (0.27 mgd)	45,000
3,785 m^3/day (1.0 mgd)	109,000

Capital Amortization--Since no adjustment is required in the capital cost, similarly the amortization would be the same as shown in Table 40.

Flow	Capital Amortization
378.5 m^3/day (0.1 mgd)	$11,000
1,022 m^3/day (0.27 mgd)	$17,000
3,785 m^3/day (1.0 mgd)	$24,000

Total Annualized Cost--The total annualized cost would be reduced because of decreased operating cost. A summary is shown below.

Flow	Total Annualized Cost
378.5 m^3/day (0.1 mgd)	$41,000/yr $1.12/3,785 ℓ ($1.12/1,000 gal.)
1,022 m^3/day (0.27 mgd)	$62,000/yr $0.63/3,785 ℓ ($0.63/1,000 gal.)
3,785 m^3/day (1.0 mgd)	$133,000/yr $0.36/3,785 ℓ ($0.36/1,000 gal.)

Thus, it can be seen that a reduction in feedwater chlorine concentration from 174 mg/l to 63.6 mg/l will result in a total annualized cost savings of almost 50 percent.

SECTION 7

PRIORITY POLLUTANT DISCUSSION

INTRODUCTION

Priority pollutant analyses were performed on coke plant wastewater samples collected during two phases of operations. During Phase 1 the coke plant waste was treated in a mode consisting of chlorination, filtration, and activated carbon adsorption. In Phase 2 the carbon adsorption process was replaced by a chemical dechlorination operation. A schematic of the wastewater treatment system is given in Figure 30.

A total of 63 samples plus blanks were collected during December, 1979 and January, 1980. The priority pollutant sampling was conducted by Davis and Floyd Engineers, Inc. under subcontract to Southern Research Institute (SRI). Organic priority pollutant analyses were performed by Acurex, Mountain View, California and metal priority pollutant analysis by Battelle Columbus Laboratories. All sampling and analysis was performed in accordance with the EPA screening protocol.

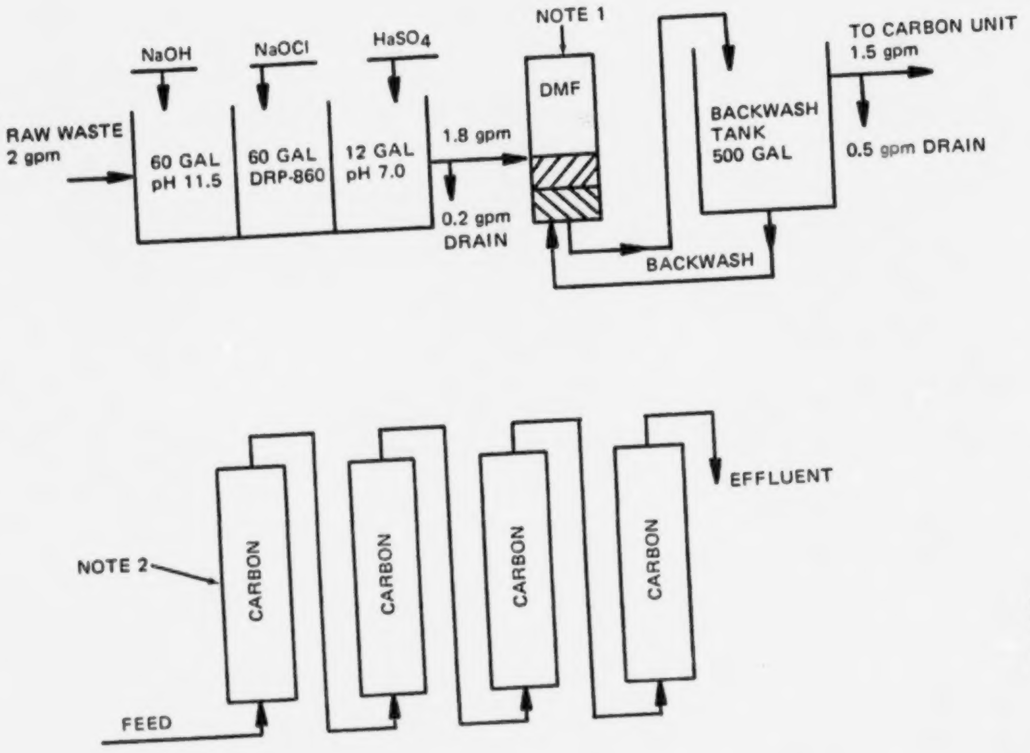
RESULTS

This section describes the results of the priority pollutant analysis performed on the coke plant wastewater samples taken during Phases 1 and 2. A site reference sampling code for the samples taken is given in Tables 41 and 42. Verification analyses were performed for volatile organics, semivolatile organics, and metals. BAT effluent limitations guidelines for by-product cokemaking plant physical-chemical treatment systems are presented in Table 43.

Phase 1

Volatile Organics--

The results of the Phase 1 volatile organics verification analyses are presented in Appendix B-3. The raw waste influent contained concentrations of benzene, acrylonitrile, and toluene exceeding the BAT limitations. Chlorination of the influent resulted in decreasing the concentration of these three pollutants by approximately half, however levels still were approximately 50 to 750 times above the BAT limits. Only trace amounts of chloroform and dichlorobromomethane were found in the influent. Chlorination increased chloroform concentrations from the 8 to 170 μg/l found in


NaOH
NaOCl
HaSO4
NOTE 1
RAW WASTE
2 gpm
60 GAL
pH 11.5
60 GAL
DRP-860
12 GAL
pH 7.0
1.8 gpm
0.2 gpm
DRAIN
DMF
BACKWASH
TANK
500 GAL
BACKWASH
TO CARBON UNIT
1.5 gpm
0.5 gpm DRAIN
NOTE 2
CARBON
CARBON
CARBON
CARBON
EFFLUENT
FEED

NOTES:

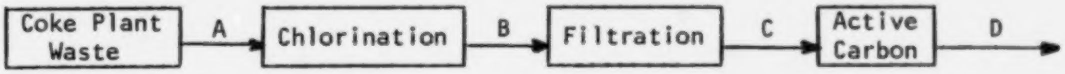
1. DUAL MEDIA FILTER CONTAINING 0.9 mm ANTHRACITE AND 0.6 mm FLINT SAND WITH 1 FT^2 SURFACE AREA OPERATED AT 55 psi.
2. CARBON COLUMNS - FOUR EACH WITH 1 FT^2 SURFACE AREA. VIRGIN FILTROSORB F300 5 FT DEEP OPERATED AT 50 psi.

4097-23

gal. x 0.26 = liters
ft x 3.28 = m
psi x 0.07 = kg/cm^2

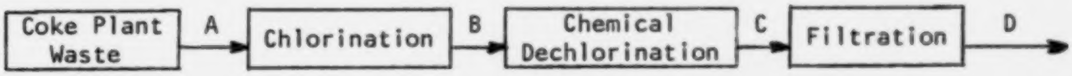
Figure 30. EPA pilot plant schematic - Shenango, Neville Island, PA.

TABLE 41. PHASE I SITE REFERENCE AND SAMPLING CODE


Coke Plant Waste
A
Chlorination
B
Filtration
C
Active Carbon
D

Date	Site A	Site B	Site C	Site D
12-4-79	06102	06103	06104	06105
12-5-79	06106	06107	06108	06109
12-6-79	06110	06111	06112	06113
12-7-79		06114	06115	06116
12-10-79	06117	06118	06119	06120
12-11-79		06121	06122	06123
12-12-79	06124	06125	06126	06127
12-13-79		06128	06129	06130
12-17-79	06134	06135	06136	06137
12-18-79		06138	06139	06140
12-19-79	06141	06142	06143	06144
12-20-79		06145	06146	06147

TABLE 42. PHASE II SITE REFERENCE AND SAMPLING CODE


Coke Plant Waste
A
Chlorination
B
Chemical Dechlorination
C
Filtration
D

Date	Site A	Site B	Site C	Site D
1-7-80	06150	06151	06152	06153
1-8-80			06154	
1-10-80	06155	06156	06157	06158
1-11-80				06159
1-14-80	06166	06167	06168	06169
1-15-80				06170
1-16-80	06171	06172	06173	06174
1-17-80				06175

TABLE 43. BAT - EFFLUENT LIMITATIONS GUIDELINES BY-PRODUCT COKEMAKING PHYSICAL/CHEMICAL TREATMENT SYSTEMS

Parameter	BAT Limitations (Alternative 2) μg/l[1]
Acrylonitrile	120
Benzene	12
Chloroform	60
Ethylbenzene	12
Fluoranthene	12
Naphthalene	12
Phenol	60
Phthalates, Total	367
Benzo(A)anthracene	12
Benzo(A)Pyrene	12
Acenaphthylene	12
Fluorene	12
Pyrene	12
Toluene	12
Xylene	12
Antimony	48
Arsenic	120
Selenium	48
Silver	12
Zinc	12

[1] Micrograms/liter based on 178 gallons of effluent per ton of coke produced.

(From Reference No. 1)

the raw influent to 3,700 to 22,000 μg/l in the chlorinated effluent. Dichlorobromomethane increased from an influent concentration of 10 to 36 μg/l to an effluent concentration of 1,700 to 4,400 μg/l through the chlorination process. While dibromochloromethane, carbon tetrachloride, 1,2 dichloroethane, chlorobenzene, and bromoform were not detected in the influent samples, significant concentrations were found in the chlorinated effluent. Filtration of the chlorinated effluent did not significantly change any of the priority pollutant concentrations except during the third week of testing when acrylonitrile unexpectedly increased 10 fold in concentration.

The final process in the Phase 1 treatment system was activated carbon adsorption. Carbon adsorption was effective in reducing the volatile organic loading; however the effluent was not in compliance with BAT effluent limitations for all monitored volatile organic compounds at all times. During the third week, the chloroform concentration in the carbon adsorption effluent was greater than 10 times the allowable effluent limit. SRI reported a chloroform spike recovery of 110 percent for the week. Benzene concentrations were approximately double the BAT limits throughout the sampling period. Benzene spike recoveries ranged from 90 percent to 130 percent. Acrylonitrile levels in the carbon effluent were 10 to 30 times over the BAT limit for the second and third week of sampling. SRI reported a poor acrylonitrile spike recovery (3,000 percent) for week two but a good recovery (110 percent) for week three.

Semivolatile Organics--

Semivolatile organics verification data are presented in Appendix B-3. Reported raw waste influent levels indicate that naphthalene, acenaphthylene, and phenol were 10 to 200 times over the BAT limitations. Fluorene and benzo(a)pyrene concentrations were found to be approximately twice the allowable limit. After the influent was chlorinated, the only semivolatile pollutant present in gross amounts was naphthalene, which was found in concentrations up to 50 times the BAT limitation. Naphthalene remained in the treated wastewater through the filtration process. The activated carbon adsorption process removed all semivolatile organics including naphthalene to well below the BAT effluent limits. Reported recoveries at detectable levels for semivolatile organics ranged from 45 percent to 140 percent.

Metals--

Metals verification analyses results are also presented in Appendix B-3. The raw waste influent contained concentrations of zinc up to 30 times and selenium up to 10 times the allowable BAT effluent limitation guidelines. The chlorination, filtration, and activated carbon processes were not effective in lowering the concentrations of these two priority pollutants. Zinc concentrations in the activated carbon effluent ranged from 88 μg/l to 220 μg/l, and selenium ranged from 130 μg/l to 345 μg/l during the three week Phase 1 sampling period. Consequently, the Phase 1 final effluent failed to meet BAT effluent limitations for zinc and selenium. Reported results indicate that BAT limits were met through the Phase 1 system for arsenic, antimony, and silver.

Phase 2

Volatile Organics--
Phase 2 volatile organics verification analytical results are presented in Appendix B-3. The raw coke plant waste contained concentrations of benzene, acrylonitrile, and toluene approximately two orders of magnitude above the BAT limits.

Chlorination reduced the concentrations of benzene, acrylonitrile, and toluene by less than one order of magnitude. Influent chloroform concentrations ranged from 7 to 22 µg/l, well within the effluent limitation. Chloroform concentration in the chlorinated effluent increased from 11,000 to 42,500 µg/l, greatly exceeding the BAT limits. The other volatile organic compounds were not detected in the raw influent, however, after chlorination significant concentrations were present. The chemical dechlorination process did not significantly decrease the volatile organic concentration of the waste stream. Likewise the final process in the Phase 2 operation, filtration, did not reduce the volatile organics concentration in the effluent. Reported chloroform, benzene, acrylonitrile, and toluene concentrations are at least an order of magnitude over the BAT effluent limits. The quality assurance summary submitted by SRI indicates good recoveries ranging from 79 percent to 139 percent for benzene, acrylonitrile, and toluene. Initial chloroform spike recoveries were poor as a result of spiking at too low of a concentration, however additional chloroform quality assurance showed recoveries of 75 percent and 140 percent.

Semivolatile Organics--
Semivolatile organics verification data for Phase 2 are shown in Appendix B-3. The raw waste influent contained naphthalene and phenol at two orders of magnitude, and acenaphthylene at one order of magnitude over the BAT limits. Fluorene, pyrene, and benzo(a)pyrene concentrations were double the effluent limit. After chlorination the semivolatile organics were generally close to the BAT limits except for naphthalene. The naphthalene concentration in the chlorinated effluent exceeded the BAT limit by a factor of twenty-five and after chemical dechlorination the concentration in the effluent increased slightly. The filtration process reduced all semivolatile organics concentration to within BAT effluent limitations except for naphthalene. Naphthalene concentrations in the filtered effluent ranged from 82 µg/l to 1,300 µg/l during the sampling period. SRI reported naphthalene spike recoveries of 60 percent and 108 percent.

Metals--
Results of the priority pollutant metals analyses are given in Appendix B-3. Reported zinc concentrations in the raw waste influent exceeded the BAT limitation, while selenium, silver, and arsenic were generally below the guidelines. Zinc and selenium levels in the chlorinated effluent were more than double the concentration in the influent. The chemical dechlorination process did not have a significant effect on any of the metal priority pollutant concentrations. After filtration, the final Phase 2 process, zinc concentrations again approximately doubled. Final effluent

zinc and selenium concentration exceeded BAT effluent limits. No explanation is available for the apparent 10 fold increase in zinc concentration and the doubling of the selenium concentration through the Phase 2 operation. Silver and arsenic concentrations in the filtered effluent remained within the effluent limitations throughout Phase 2. Data on antimony is not sufficient to evaluate what effect the Phase 2 operation had on this metal or compliance with BAT limitations.

Summary

Results of the priority pollutant analyses performed on the coke plant waste can be used to evaluate the effectiveness of the two operational phases in reducing pollutant loading.

Volatile Organics--

Neither Phase 1 or Phase 2 treatment systems appear to be completely effective in the removal of volatile organic priority pollutants. However, Phase 1 processes were superior, removing 10 to 100 times more volatile organics than Phase 2. Although the Phase 1 treatment system removed volatile organics from the wastestream, the final effluent was not in compliance with BAT limits for chloroform, benzene, and acrylonitrile for all of the sampling periods. Phase 1 final effluent contained lower concentrations of benzene, acrylonitrile, and toluene than initially present in the raw waste. Effluent chloroform levels were greater than the raw influent levels during the third sampling week of Phase 1.

Volatile organic priority pollutants were not effectively removed in the Phase 2 treatment operation. Comparison of raw influent to final effluent concentrations shows acrylonitrile decreased two and toluene decreased one order of magnitude while chloroform increased three orders of magnitude and benzene increased slightly. Significant amounts of other volatile organics not detected in the raw waste were found in the final effluent. All BAT volatile organics were greater than 10 times over the allowable effluent limits.

Semivolatile Organics--

Phase 1 provided a more complete semivolatile organic priority pollutant removal than Phase 2. Phase 2 treatment processes removed all semivolatile organic priority pollutants initially present in the raw waste to below BAT limits with the exception of naphthalene. Naphthalene concentrations in the final Phase 2 effluent were 10 to 100 times the BAT limit.

The Phase 1 operation was effective in removing all semivolatile organic priority pollutants to well below BAT effluent limits, including naphthalene.

Metals--

Phase 1 treatment processes did not appear to be effective in removing priority pollutant metals. Phase 1 final effluent BAT metals concentrations are very close to the initial raw influent levels. Results indicate that

BAT limits were met for arsenic, antimony, and silver but not for zinc and selenium. Priority pollutant metals were not removed in the Phase 2 operation. Silver and arsenic concentrations were below the BAT limits in the raw waste and remained in compliance through Phase 2 operations. Final effluent zinc and selenium concentrations exceeded BAT limits. Final effluent zinc concentrations increased 10 fold and selenium doubled during the Phase 2 operation.

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APPENDIX A. COKE PLANT PRODUCTION FIGURES AND BAT EFFLUENT LIMITATIONS

Date	Plant Discharge		Ammonia		Cyanide-T		Oil & Grease		Phenol		Sulfide		Suspended Solids		Thiocyanate	
	Tons Coke	Flow mgd	mg/l	lbs/ day	mg/l	lbs/ day	mg/l	lbs/ day	mg/l	lbs/ day	mg/l	lbs/ day	mg/l	lbs/ day	mg/l	lbs/ day
11/1/79	1410.35	-	-	25.64	-	0.64	-	25.64	-	0.51	-	0.77	-	51.3	-	383.6
11/2/79	1612.10	-	-	29.30	-	0.73	-	29.30	-	0.59	-	0.88	-	58.7	-	438.5
11/3/79	1603.55	-	-	29.15	-	0.73	-	29.15	-	0.58	-	0.87	-	58.3	-	436.2
11/4/79	1461.95	-	-	26.58	-	0.66	-	26.58	-	0.53	-	0.80	-	53.2	-	397.7
11/5/79	1586.70	-	-	28.84	-	0.72	-	28.84	-	0.58	-	0.86	-	57.8	-	431.6
11/6/79	1457.14	-	-	26.49	-	0.66	-	26.49	-	0.53	-	0.80	-	53.0	-	396.3
11/7/79	1319.35	-	-	25.99	-	0.60	-	23.99	-	0.48	-	0.72	-	48.0	-	358.9
11/8/79	1680.90	-	-	30.56	-	0.76	-	30.56	-	0.61	-	0.92	-	61.2	-	457.2
11/9/79	1519.65	-	-	27.63	-	0.69	-	27.63	-	0.55	-	0.83	-	55.3	-	413.3
11/10/79	1431.10	-	-	26.02	-	0.65	-	26.02	-	0.52	-	0.78	-	52.1	-	389.2
11/11/79	1604.25	-	-	29.16	-	0.73	-	29.16	-	0.58	-	0.88	-	58.4	-	436.4
11/12/79	1531.70	-	-	27.85	-	0.69	-	27.85	-	0.56	-	0.84	-	55.8	-	416.6
11/13/79	1609.55	-	-	29.26	-	0.73	-	29.26	-	0.58	-	0.88	-	58.6	-	437.8
11/14/79	1484.55	-	-	26.99	-	0.67	-	26.99	-	0.54	-	0.81	-	54.0	-	403.8
11/15/79	1534.75	-	-	27.90	-	0.70	-	27.90	-	0.56	-	0.84	-	55.9	-	417.4
11/16/79	1549.65	-	-	28.17	-	0.70	-	28.17	-	0.56	-	0.85	-	56.4	-	421.5
11/17/79	1389.70	-	-	25.26	-	0.63	-	25.26	-	0.50	-	0.76	-	50.6	-	378.0
11/18/79	1574.50	-	-	28.62	-	0.71	-	28.62	-	0.57	-	0.86	-	57.3	-	428.3
11/19/79	1592.30	-	-	29.06	-	0.72	-	29.06	-	0.58	-	0.87	-	58.2	-	434.7
11/20/79	1527.35	-	-	27.78	-	0.69	-	27.78	-	0.55	-	0.83	-	55.6	-	415.4
11/21/79	1516.30	-	-	27.58	-	0.69	-	27.58	-	0.55	-	0.83	-	55.2	-	412.6
11/22/79	1561.50	-	-	28.39	-	0.71	-	28.39	-	0.57	-	0.85	-	56.8	-	424.7
11/23/79	1557.00	-	-	28.31	-	0.71	-	28.31	-	0.57	-	0.87	-	56.7	-	423.5
11/24/79	1494.45	-	-	27.17	-	0.69	-	27.17	-	0.54	-	0.82	-	54.4	-	406.5
11/25/79	1552.35	-	-	28.22	-	0.70	-	28.22	-	0.56	-	0.85	-	56.5	-	422.3
11/26/79	1636.41	-	-	29.75	-	0.74	-	29.75	-	0.60	-	0.89	-	59.6	-	445.1
11/27/79	1429.05	-	-	25.98	-	0.65	-	25.98	-	0.52	-	0.78	-	52.0	-	388.7
11/28/79	1563.30	-	-	28.42	-	0.71	-	28.42	-	0.57	-	0.85	-	56.9	-	425.2
11/29/79	1510.60	0.2536	12.98	27.46	0.32	0.68	12.98	27.46	0.26	0.55	0.39	0.82	26.0	55.0	194.3	410.9
11/30/79	1548.10	0.3580	9.98	28.14	0.25	0.70	9.98	28.14	0.20	0.56	0.30	0.84	20.0	56.3	149.4	421.1
12/1/79	1467.55	0.3851	8.30	26.68	0.21	0.67	8.31	26.68	0.16	0.53	0.25	0.80	16.6	53.4	124.3	399.2
12/2/79	1597.55	0.3851	9.04	29.04	0.22	0.72	9.04	29.04	0.18	0.58	0.27	0.87	18.1	58.1	135.3	434.5
12/3/79	1381.05	0.3851	7.82	25.11	0.20	0.63	7.82	25.11	0.15	0.50	0.23	0.75	15.7	50.3	116.9	375.6
12/4/79	1585.00	0.2899	11.91	28.81	0.30	0.72	11.91	28.81	0.24	0.58	0.35	0.86	23.9	57.7	178.3	431.1
12/5/79	1514.20	0.2899	11.39	27.53	0.28	0.69	11.40	27.53	0.23	0.55	0.34	0.83	22.8	55.1	170.4	411.9
12/6/79	1437.20	0.2608	12.01	26.13	0.30	0.65	12.01	26.13	0.24	0.52	0.36	0.78	24.0	52.3	179.7	390.9
12/7/79	1635.50	0.2801	12.33	29.73	0.31	0.74	12.33	29.73	0.24	0.59	0.37	0.89	24.7	59.5	184.5	444.8
12/8/79	1489.30	0.3036	10.69	27.07	0.27	0.68	10.69	27.07	0.21	0.54	0.32	0.81	21.4	54.2	160.0	405.1

(continued)

APPENDIX A. (continued)

	Plant Discharge		Ammonia		Cyanide-T		Oil & Grease		Phenol		Sulfide		Suspended Solids		Thiocyanate	
Date	Tons Coke	Flow mgd	mg/l	lbs/ day	mg/l	lbs/ day	mg/l	lbs/ day	mg/l	lbs/ day	mg/l	lbs/ day	mg/l	lbs/ day	mg/l	lbs/ day
12/9/79	1476.90	0.2980	10.80	26.85	0.27	0.67	10.50	26.85	0.22	0.54	0.33	0.81	21.6	53.7	161.6	401.7
12/10/79	1624.45	0.2886	12.27	29.53	0.31	0.74	12.27	29.53	0.24	0.59	0.37	0.89	24.5	59.1	183.6	441.8
12/11/79	1539.75	0.2948	11.38	27.99	0.28	0.70	11.38	27.99	0.23	0.56	0.34	0.54	22.8	56.0	170.3	418.8
12/12/79	1434.85	0.2965	10.55	26.08	0.26	0.65	10.54	26.08	0.21	0.52	0.31	0.78	21.1	52.2	157.8	390.3
12/13/79	1642.25	0.3074	11.65	29.86	0.29	0.74	11.65	29.86	0.23	0.60	0.35	0.90	23.3	59.8	174.2	446.7
12/14/79	1578.30	0.2747	12.52	28.69	0.31	0.72	12.52	28.69	0.25	0.57	0.37	0.86	25.0	57.4	187.4	429.3
12/15/79	1615.60	0.2738	12.86	29.37	0.32	0.73	12.86	29.37	0.26	0.59	0.38	0.83	25.7	58.8	192.4	439.4
12/16/79	1459.95	0.2738	11.62	26.54	0.29	0.66	11.62	26.54	0.23	0.53	0.35	0.80	23.2	53.1	173.9	397.6
12/17/79	1471.34	0.2932	10.96	26.80	0.27	0.67	10.96	26.80	0.22	0.54	0.33	0.80	22.0	53.7	164.0	401.0
12/18/79	1509.85	0.3091	10.65	27.45	0.26	0.68	10.65	27.45	0.21	0.55	0.32	0.82	21.3	55.0	159.3	410.7
12/19/79	1574.05	0.2439	14.06	28.61	0.35	0.71	14.06	28.61	0.28	0.57	0.42	0.86	28.2	57.3	210.5	428.1
12/20/79	1672.88	0.2859	12.75	30.41	0.32	0.76	12.75	30.41	0.25	0.61	0.38	0.91	25.5	60.9	190.8	455.0
12/21/79	1525.65	-	-	-	-	-	-	-	-	-	-	0.83	-	55.5	-	-
12/22/79	1499.00	-	-	-	-	-	-	-	-	-	-	0.82	-	54.6	-	-
12/23/79	1646.20	-	-	-	-	-	-	-	-	-	-	0.90	-	59.9	-	-
12/24/79	1618.35	-	-	-	-	-	-	-	-	-	-	0.88	-	58.9	-	-
12/25/79	1439.70	-	-	-	-	-	-	-	-	-	-	0.79	-	52.4	-	-
12/26/79	1482.60	-	-	-	-	-	-	-	-	-	-	0.81	-	54.0	-	-
12/27/79	1593.55	-	-	-	-	-	-	-	-	-	-	0.87	-	58.0	-	-
12/28/79	1573.40	-	-	-	-	-	-	-	-	-	-	0.86	-	57.3	-	-
12/29/79	1361.25	-	-	-	-	-	-	-	-	-	-	0.74	-	49.5	-	-
12/30/79	1560.80	-	-	-	-	-	-	-	-	-	-	0.85	-	56.8	-	-
12/31/79	1520.45	-	-	-	-	-	-	-	-	-	-	0.83	-	55.3	-	-
1/1/80	1560.75	-	-	-	-	-	-	-	-	-	-	0.85	-	56.8	-	-
1/2/80	1442.80	-	-	-	-	-	-	-	-	-	-	0.79	-	52.5	-	-
1/3/80	1509.35	-	-	-	-	-	-	-	-	-	-	0.82	-	54.9	-	-
1/4/80	1459.20	0.2528	12.58	26.53	0.31	0.66	12.58	26.53	0.25	0.53	0.38	0.80	25.2	53.1	188.2	396.9
1/5/80	1493.85	0.2771	11.75	27.16	0.29	0.68	11.75	27.16	0.23	0.54	0.35	0.82	23.5	54.4	175.8	406.3
1/6/80	1551.40	0.2445	13.83	28.20	0.34	0.70	13.83	28.20	0.28	0.56	0.41	0.85	27.7	56.5	206.9	422.0
1/7/80	1461.88	0.3045	10.46	26.58	0.26	0.66	10.46	26.58	0.21	0.53	0.31	0.80	20.9	53.2	156.6	397.6
1/8/80	1573.00	0.2568	13.35	28.60	0.33	0.71	13.35	28.60	0.27	0.57	0.40	0.86	26.7	57.3	199.8	427.9
1/9/80	1468.60	0.2703	11.84	26.70	0.30	0.67	11.84	26.70	0.24	0.53	0.36	0.80	23.7	63.5	177.2	399.5
1/10/80	1564.50	0.1470	23.20	28.44	0.58	0.71	23.20	28.44	0.46	0.57	0.70	0.85	46.4	56.9	347.1	425.5
1/11/80	1398.55	0.0994	30.67	25.43	0.77	0.63	30.67	25.43	0.61	0.51	0.92	0.76	61.4	50.9	458.9	380.4
1/12/80	1572.00	0.0975	35.15	28.58	0.88	0.71	35.15	28.58	0.70	0.57	1.05	0.86	70.4	57.2	525.8	427.6
1/13/80	1486.65	0.2048	15.82	27.03	0.39	0.67	15.82	27.03	0.32	0.54	0.47	0.81	31.7	54.1	236.7	404.4
1/14/80	1563.60	0.1787	19.07	28.43	0.48	0.71	19.07	28.43	0.38	0.57	0.57	0.85	38.2	56.9	285.4	425.3
1/15/80	1448.90	0.2542	12.42	26.34	0.31	0.66	12.42	26.34	0.25	0.53	0.37	0.79	24.9	52.7	185.9	394.1
1/16/80	1460.80	0.2510	12.69	26.56	0.32	0.66	12.69	26.56	0.25	0.53	0.38	0.80	25.4	53.2	189.9	397.3
1/17/80	1465.60	0.2807	11.38	26.64	0.28	0.66	11.38	26.64	0.23	0.53	0.34	0.80	22.8	53.3	170.3	398.6
1/18/80	1466.65	0.2796	11.43	26.66	0.28	0.67	11.43	26.66	0.23	0.53	0.34	0.80	22.9	53.4	171.1	398.9
1/19/80	1405.70	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
1/20/80	1468.75	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
1/21/80	1698.25	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
AVE.	1519.04	0.2708	13.36	27.61	0.33	0.69	13.36	27.61	0.27	0.55	0.40	0.83	26.7	55.5	199.8	402.1

APPENDIX B-1. BENCH SCALE TESTING

INTRODUCTION

Bench scale treatment tests were performed by the Environmental Research Center of Rexnord on a sample of equalized effluent from a coke by-product plant. The laboratory bench scale tests were performed in the Rexnord laboratory from October 24 - November 7, 1979. The purpose of these tests was to investigate treatment feasibility, obtain basic design data for the pilot plant; determine waste pretreatment requirements; and generate the information required to plan the pilot plant tests. The bench scale processes investigated were alkaline chlorination, filtration, activated carbon dechlorination, and sodium bisulfite dechlorination.

The bench tests were performed to investigate treatment methods for meeting BAT effluent requirements for the by-product coke subcategory(1). The target effluent concentrations are defined as follows:

Parameter	Target effluent concentration to meet BAT requirement
pH	6-9
Ammonia	<10 mg/l
Cyanide-T	<0.25 mg/l
Thiocyanate	<150 mg/l
Phenol	<0.2 mg/l
Sulfide	<0.3 mg/l
Suspended Solids	<20 mg/l
Oil & Grease	<10 mg/l

Samples were procured from the plant equalization basin on October 23, 1979.

EXPERIMENTAL EQUIPMENT AND PROCEDURES

Alkaline Chlorination Test Procedure

Chlorine oxidation tests were performed on the raw wastewater to determine its effectiveness in removing phenol, cyanide and ammonia. The wastewater was adjusted to a pH of 11.5 ± 0.5 with sodium hydroxide and chlorine in the form of sodium hypochlorite was added. The wastewater was held for 7 minutes, then the pH was lowered to 7.4 ± 0.3 with hydrochloric acid. The detention time was based on literature values (7)(8). The effectiveness of direct filtration and chemical clarification in removing suspended solids in the chlorinated wastewater were also compared. Residual chlorine was measured immediately on the samples. Excess chlorine was removed from the ammonia and cyanide samples with ascorbic acid and the samples were preserved for later analysis.

Carbon Adsorption Test Equipment and Procedure

Pulverized activated carbon was obtained directly from the manufacturers for use in these tests. Weights of carbon ranging from about 0.01 g (0.004 oz.) to about 10.0 g (0.36 oz.) were placed in seven flasks from each carbon isotherm test. Tests were performed using 250 ml (0.066 gal.) sample per flask. In addition, an eighth flask containing sample but no carbon was used as a blank. After shaking for 20 minutes using a Burrell Wrist-Action Shaker, the contents of the eight flasks were filtered through washed 0.45 μm membrane filters to remove suspended material. The filtrate was saved for analysis.

Bisulfite Test Procedure

Bisulfite dechlorination testing involved adding sodium bisulfite at 70%, 100%, and 130% of the stoichiometric ratio of 1.4 mg $NaHSO_3$/mg Cl_2 to three flasks containing 50 ml (0.021 gal.) wastewater with an initial chlorine concentration of 80 mg/l. Residual chlorine was measured immediately after bisulfite addition.

Analytical Procedures

The following analytical procedures were used. In this listing, Standard Methods refers to Standard Methods for the Examination of Water and Wastewater, 14th Ed., APHA, AWWA, and WPCF, 1975 (4).

1. pH - Beckman Electromate pH meter, Standard Methods, p. 460.
2. Turbidity - Hach Model 2100A turbidimeter, Standard Methods, p. 132.
3. BOD - Standard Methods, p. 543.
4. Total Organic Carbon (TOC) - Beckman Model 915A TOC analyzer Standard Methods, p. 532.
5. Suspended Solids - Standard Methods, p. 94.
6. Oil and Grease - Standard Methods, p. 515.
7. Sulfate - Standard Methods, p. 496.
8. Chloride - Standard Methods, p. 304.
9. Metals - Na, K, Mn, Fe, Al, Ca, Mg - Standard Methods, p. 144.
10. Ammonia, Orion Ion Specific Electrode - EPA Methods for Chemical Analysis of Water and Waste, 1974, p. 165.
11. Cyanide - Distillation followed by Orion Ion Specific Electrode, Standard Methods, p. 367.

12. Acidity - Standard Methods, p. 273.
13. Sulfide - Standard Methods, p. 503.
14. Residual Chlorine - Iodometric Titration, Standard Methods, p. 318.

RAW WASTE CHARACTERISTICS

Comparison of BPT/BAT Effluent Limitations and Raw Waste

The comparison between the waste sample analytical values and the by-product coke subcategory BPT and BAT (non-priority pollutant) limitations are shown in Table B-1.1. For those parameters controlled by BPT limitations (ammonia, cyanide-T, thiocyanate, phenol, sulfide, suspended solids, and pH), the pH, ammonia, phenol, and suspended solids limits were exceeded. All BAT limitations were exceeded except for the oil and grease limitations. This indicates that further treatment will be necessary to meet future federal BAT effluent goals. The objective of this bench testing program was to investigate various advanced treatment technologies for meeting by-product coke BAT limitations. The results and recommendations of the bench study are presented in the following sections.

Results of the Chlorine Oxidation Tests

The raw waste samples were pH adjusted with NaOH to allow for efficient oxidation of cyanide to cyanate (pH 11.5 ± 0.2) and ammonia to N_2 and CO_2 (pH 7.4 ± 0.3) (4). The four chlorination levels selected (Table B-1.2) were meant to bracket the theoretical reaction ratio of chlorine to ammonia of 7.6 to 1 (9)(10). Test numbers 1, 2, 3, and 4 were treated with a chlorine dose based on 70%, 100%, 130%, and 150% of the theoretical reaction ratio. Only Test #4 was effective in reducing the ammonia below the BAT limit. The cyanide amenable to chlorination and phenol BAT limits were exceeded. It is expected that the CN_A and phenol concentrations would be reduced during activated carbon dechlorination.

Chemical clarification using $FeCl_3$ and polyelectrolyte was compared with direct filtration for suspended solids removal. Chemical clarification was not effective in removing suspended solids while direct filtration proved quite effective.

Results of the Activated Carbon Dechlorination Test

Samples from the chlorination tests were filtered and treated with activated carbon to remove residual chlorine. These carbon isotherm tests indicated that 0.10 mg chlorine would be adsorbed per gram of carbon in reducing the effluent chlorine concentration to less than 1.0 mg/l.

Results of the Bisulfite Dechlorination Test

Samples from the chlorination tests were filtered and treated with sodium bisulfite to remove residual chlorine. Bisulfite addition rates of 70%, TABLE B-1.1. BY-PRODUCT COKE BPT/BAT EFFLUENT LIMITATIONS

Parameter	BPT	Waste sample	BAT
pH units	6-9	3.5	6-9
NH_3 as N	125	307	10
CN_A	30	12.4	0.25
CN_T		16.7	
Thiocyanate	450	177	150
Phenol	2	190	0.2
Sulfide	40	15.8	0.3
Suspended solids	50	73	20
Dissolved solids		2,741	
Turbidity NTU		25	
Acidity as $CaCO_3$		300	
BOD_5		201	
TOC		228	
Oil & grease	15	3	10
Chloride		1,210	
Sulfate		1,090	
Sodium		790	
Potassium		1.8	
Calcium		3.8	
Magnesium		4.4	
Iron		8.3	
Manganese		1.3	

Note: All units are mg/l unless noted otherwise.

TABLE B-1.2. ALKALINE CHLORINATION TESTS

		Test			
	Raw	1	2	3	4
Chlorine dose (available chlorine, mg/l)		1,935	2,765	3,600	4,150
Cyanide amenable to chlorination, mg/l	12.4				1.45
Total cyanide, mg/l	16.7	2.14	1.22	1.70	2.01
Thiocyanate, mg/l	177				<0.1
Ammonia-N, mg/l	307	255	100	28	7.7
Phenol, mg/l	190				1.6
Residual chlorine, mg/l		525	70	105	270

100% and 130% of the theoretical ratio of 1.4 mg bisulfite per 1.0 mg chlorine were evaluated. The bench scale tests indicated that a ratio of 1.8 mg bisulfite is required to remove 1.0 mg of chlorine. The pH of the samples did not change due to the bisulfite addition.

Recommendations for Pilot Tests

It is recommended that alkaline chlorination, filtration, and dechlorination be investigated in the pilot test phase. Activated carbon adsorption and sodium bisulfite addition should be compared as dechlorination processes.

Based on the sample tested, 13.5 mg chlorine per mg ammonia would be required to reduce the ammonia concentration to less than 10 mg/l. The suspended solids present in the chlorinated wastewater can be removed by dual media filtration. The residual chlorine can be removed using activated carbon adsorption or sodium bisulfite addition. Activated carbon adsorbed chlorine in the ratio of 0.1 mg chlorine/gm carbon. Dechlorination to less than 1.0 mg/l required the addition of 1.8 mg bisulfite/mg chlorine removed.

It should be noted that the chlorination step alone was ineffective in reducing the cyanide and phenol concentrations to acceptable levels. The combination of alkaline chlorination and carbon adsorption should be effective in removing cyanide-T and phenol.

APPENDIX B-2. PILOT STUDY CONVENTIONAL POLLUTANT DATA SUMMARY

APPENDIX B-2. PILOT STUDY DATA SUMMARY

Date	Suspended solids, mg/l	Phenol, mg/l	Ammonia, mg/l	Sulfide, mg/l	$Cyanide_T$, mg/l	$Cyanide_A$, mg/l	Thiocyanate, mg/l	Total Kjeldahl nitrogen, mg/l	Total dissolved solids, mg/l	Chlorides, mg/l	Color APHA units	Oil & grease, mg/l	Nitrate/Nitrite-N mg/l	BOD, mg/l	TOC, mg/l
Raw Wastewater															
11/30/79	353	58	717	26	100.0	80.2	205	815	6380	1525	280	-	-	-	400
12/3/79	69	80	224	27	130.0	123.5	320	4120	-	-	-	-	-	-	330
12/4/79	48	56	241	19	125.9	124.3	235	-	-	-	-	3	-	-	425
12/5/79	40	110	370	20	102.7	98.6	210	450	2930	1125	160/200	-	-	-	230
12/6/79	35	124	142	16	83.8	76.7	155	-	-	-	-	-	-	-	336
12/7/79	152	70	260	26	70.7	57.1	260	344	3735	1375	300	6	1.3	525	415
12/8/79	57	-	167	-	64.0	56.5	-	-	-	-	-	-	-	-	-
12/9/79	58	-	170	-	69.5	65.6	-	-	-	-	-	-	-	-	-
12/10/79	55	26	126	26.9	145.0	117.2	300	169	4150	1620	400	3	-	-	368
12/11/79	65	68	106	24.0	267.5	261.4	300	-	-	-	-	-	-	-	376
12/12/79	97	-	101	24.6	99.6	66.7	290	167	4580	1620	300	-	3.7	-	304
12/13/79	52	80	216	25.9	97.7	93.3	290	-	-	-	-	-	-	-	352
12/14/79	68	850	329	24.8	79.7	62.7	300	335	4070	1560	300	10	2.0	450	348
12/15/79	-	-	637	-	58.0	29.0	-	-	-	-	-	-	-	-	-
12/15/79	-	-	467	-	63.0	19.5	-	-	-	-	-	-	-	-	-
12/15/79	-	-	347	-	67.3	39.6	-	-	-	-	-	-	-	-	-
12/15/79	-	-	315	-	56.6	30.8	-	-	-	-	-	-	-	-	-
12/16/79	-	-	216	-	75.0	0.5	-	-	-	-	-	-	-	-	-
12/17/79	171	80	200	27.3	83.8	82.4	320	-	-	-	-	-	-	-	430
12/18/79	123	80	193	25.7	83.0	71.3	295	260	4150	1500	400/600	11	2.5	-	546
12/19/79	106	60	260	27.3	131.3	112.2	275	-	-	-	-	-	-	-	445
12/20/79	64	70	235	26.4	105.0	97.1	275	-	-	-	300/400	-	-	-	444
1/7/80	67	-	800	-	64.0	50.5	240	-	-	-	-	-	-	-	-
1/8/80	116	130	1925	26	44.4	11.0	255	-	-	-	100/150	138	2.0	-	618
1/9/80	116	130	1925	26	44.4	11.0	255	-	-	-	100/150	138	-	-	618
1/9/80	247	-	2150	-	40.5	1.6	250	-	-	-	-	-	-	-	-
1/10/80	197	280	2130	260	4.7	2.4	2	2190	-	-	300/400	147	-	-	-
1/11/80	361	38	800	11.6	16.1	13.9	185	-	5960	-	100/150	139	-	-	515
1/13/80	66	154	390	-	80.2	81.5	260	-	-	-	150/200	-	-	-	465
1/15/80	52	156	203	150	99.2	93.2	215	-	-	-	150/200	-	-	-	380
1/16/80	71	120	204	106	127.5	121.5	315	-	-	-	500/600	53	-	-	-
1/16-17/80	60	170	184	82.8	85.0	84.9	460	-	-	-	300/400	40	-	-	550
1/17/80	26	130	161	38.7	87.4	86.0	330	-	-	-	600/700	40	3.1	-	445
Cyanide Oxidation Tank															
11/29-30/79	305	-	106	-	19.0	<0.05	27	-	36,600	-	300/400	-	-	-	-
11/30/79	167	-	110	-	9.3	1.2	0	-	35,000	-	200	-	-	-	-
12/3/79	67	-	11	<0.2	5.0	6.0	<1	-	-	-	-	-	-	-	205
12/4/79	-	-	34	-	0.4	<0.05	3	-	-	-	-	-	-	-	105

(continued)

APPENDIX B-2. (continued)

Date	Suspended solids mg/l	Phenol, mg/l	Ammonia, mg/l	Sulfide, mg/l	Cyanide$_T$, mg/l	Cyanide$_A$, mg/l	Thiocyanate, mg/l	Total Kjeldahl nitrogen mg/l	Total dissolved solids mg/l	Chlorides, mg/l	Color APHA units	Oil & grease, mg/l	Nitrate/Nitrite-N mg/l	BOD, mg/l	TOC, mg/l
Dual Media Filter Effluent															
11/30/79	13	0.9	90	<0.2	12.7	2.2	3	130	22,300	8,850	300/400	-	-	-	355
12/3/79	17	0.40	34	<0.2	6.8	5.8	<1	-	19,600	-	-	-	-	-	125
12/4/79	16	0.50	140	<0.2	0.5	<0.05	<1	-	-	-	-	3	-	-	90
12/5/79	8	0.30	20	<0.2	0.6	<0.05	<1	-	20,200	8,000	140	-	-	-	115
12/6/79	10	0.30	30	<0.2	2.7	<0.05	<1	-	-	-	-	-	-	-	240
12/7/79	14	0.30	31	<0.2	3.7	<0.05	<1	-	16,450	7,000	200	17	5.7	222	239
12/8/79	2	-	20	-	0.1	<0.05	-	-	-	-	-	-	-	-	-
12/9/79	2	-	20	-	2.5	1.2	-	-	-	-	-	-	-	-	-
12/10/79	6	<0.01	20	<0.2	1.1	0.8	13	-	16,800	7,250	400	3	-	-	196
12/11/79	8	0.20	8	<0.2	I	I	8	-	-	-	-	-	-	-	206
12/12/79	8	0.25	8	<0.2	0.2	<0.05	8	19	21,400	8,650	150	-	8.4	-	192
12/13/79	9	0.70	9	<0.2	4.6	2.4	7	-	-	-	-	-	-	-	228
12/14/79	6	0.40	11	<0.2	4.9	<0.05	14	26	19,500	8,000	300	17	5.8	28	270
12/17/79	36	0.7	10	<0.2	11.3	1.2	2	-	-	-	-	-	-	-	366
12/18/79	10	0.6	13	<0.2	11.5	2.6	25	-	17,600	6,750	200/300	3	5.0	-	270
12/19/79	8	0.6	11	<0.2	6.9	1.2	8	-	-	-	-	-	-	-	270
12/20/79	10	1.2	9	<0.2	10.0	2.4	<1	-	-	-	150/200	-	-	-	240
1/7/80	6	-	40	-	0.8	<0.05	4	-	-	-	-	-	-	-	-
1/8/80	3	0.05	26	<0.2	I	I	45	-	-	-	80/100	43	9.9	-	516
1/8/80	1	<0.05	37	<0.2	I	I	<1	-	-	-	80/100	-	-	-	-
1/9/80	4	-	43	-	4.9	3.7	-	-	-	-	-	-	-	-	-
1/10/80	9	<0.05	35	<0.2	I	I	3	56	-	-	80/100	14	-	-	-
1/11/80	2	0.3	19	<0.2	I	I	<1	-	24,200	-	75/100	11	-	-	160
1/14/80	6	1.4	34	-	9.4	<0.05	3	-	-	-	200/250	-	-	-	-
1/15/80	7	0.6	22	6.6	9.4	3.4	3	-	-	-	200/250	-	-	-	-
1/16/80	<1	1.0	16	36.1	10.3	4.9	3	-	-	-	200/250	2	-	-	-
1/17/80	1	0.6	15	99.8	4.7	2.6	5	-	-	-	200/250	-	-	-	-
1/17/80	1	<0.05	2	<0.2	I	I	4	-	-	-	300/350	2	46	-	750
Activated Carbon Effluent															
12/3/79	6	0.20	30	<0.2	I	I	<1	-	22,900	-	-	-	-	-	18
12/4/79	7	0.10	17	<0.2	0.3	<0.05	<1	-	-	-	-	<1	-	-	41
12/5/79	6	<0.01	86	0.6	0.5	<0.05	<1	-	22,600	9,250	50	-	-	-	57
12/6/79	7	<0.01	22	<0.2	-	<0.05	<1	-	-	-	-	-	-	-	52
12/7/79	14	<0.01	8	<0.2	0.5	<0.05	<1	36	14,000	6,000	250	7	5.4	167	80
12/10/79	13	<0.01	17	<0.2	0.3	0.1	8	31	18,100	7,620	40	2	-	-	62
12/11/79	7	0.10	8	<0.2	I	I	2	-	-	-	-	-	-	-	56

I = Interference

(continued)

APPENDIX B-2. (continued)

Date	Suspended solids, mg/l	Phenol, mg/l	Ammonia, mg/l	Sulfide, mg/l	Cyanide$_T$, mg/l	Cyanide$_A$, mg/l	Thio-cyanate, mg/l	Total Kjeldahl nitrogen, mg/l	Total dissolved solids, mg/l	Chlorides, mg/l	Color APHA units	Oil & grease, mg/l	Nitrate/Nitrite-N mg/l	BOD, mg/l	TOC, mg/l
Cyanide Oxidation Tank (continued)															
12/5/79	63	-	34	-	3.4	2.4	<1	-	16,900	-	60	-	-	-	90
12/6/79	-	-	65	1.5	9.4	1.9	2	-	-	-	-	-	-	-	-
12/7/79	108	-	56	-	0.2	<0.05	<1	-	16,950	-	50	-	-	-	-
12/10/79	22	-	35	-	3.2	<0.05	14	-	16,700	7,190	50	-	-	-	196
12/12/79	48	80.5	8	-	<1	I	8	-	21,500	-	75	-	5.0	-	-
12/13/79	-	-	34	-	4.6	<0.05	125	-	-	-	-	-	-	-	-
12/14/79	31	-	28	-	0.5	<0.05	8	-	27,000	-	50	-	-	-	-
12/15/79	-	-	56	-	11.9	10.0	60	-	-	-	-	-		-	-
12/18/79	27	-	21	-	6.4	1.3	95	-	19,000	-	660/800	-	-	-	-
12/19/79	-	-	36	-	5.3	0.4	12	-	-	-	-	-	-	-	-
12/20/79	52	-	54	-	11.4	0.8	20	-	-	-	100/200	-	-	-	-
Alkaline Chlorination Effluent															
11/30/79	110	0.4	55	<0.2	11.6	9.0	3	120	26,300	5,200	200/300	-	-	-	370
12/3/79	75	0.30	35	<0.2	9.4	6.4	<1	-	19,500	-	-	-	-	-	135
12/4/79	20	0.11	67	<0.2	0.2	<0.05	<1	-	-	-	-	3	-	-	120
12/5/79	34	0.30	8	<0.2	0.2	<0.05	<1	50	22,200	-	120	-	-	-	125
12/6/79	19	1.5	30	6.8	3.6	<0.05	<1	-	-	-	-	-	-	-	228
12/7/79	100	0.40	53	<0.2	3.0	<0.05	<1	84	16,050	7,250	100	15	5.0	140	275
12/8/79	40	-	17	-	1.0	1.0	-	-	-	-	-	-	-	-	-
12/9/79	38	-	17	-	6.0	1.5	-	-	-	-	-	-	-	-	-
12/10/79	34	0.80	31	<0.2	3.0	0.8	14	60	17,300	200	-	3	-	-	152
12/11/79	40	0.35	14	<0.2	I	I	65	-	-	-	-	-	-	-	272
12/12/79	35	<0.01	8	<0.2	I	I	50	-	21,200	8,750	200	-	8.5	-	192
12/13/79	24	0.55	19	<0.2	3.7	0.5	8	-	-	-	-	-	-	-	232
12/14/79	11	0.50	19	<0.2	7.9	<0.05	15	37	15,900	-	-	15	6.7	24	-
12/15/79	-	-	206	-	0.7	<0.05	-	-	-	-	-	-	-	-	-
12/15/79	-	-	60	-	0.2	5.4	-	-	-	-	-	-	-	-	-
12/15/79	-	-	8	-	10.5	0.94	-	-	-	-	-	-	-	-	-
12/15/79	-	-	17	-	10.3	<0.05	-	-	-	-	-	-	-	-	-
12/16/79	-	-	20	-	5.0	<0.05	-	-	-	-	-	-	-	-	-
12/17/79	129	1.0	9	<0.2	13.0	12.0	3	-	-	-	-	-	-	-	402
12/18/79	130	1.4	15	<0.2	12.9	3.5	65	35	17,300	-	300/400	8	6.0	-	420
12/19/79	71	1.4	14	<0.2	6.8	0.6	8	-	-	-	-	-	-	-	345
12/20/79	71	3.0	16	<0.2	0.9	<0.05	23	-	-	-	160/200	-	-	-	270
1/3/80	62	0.6	34	<0.2	I	I	85	-	-	-	50/75	21	15.4	-	696
1/4/80	50	0.4	66	<0.2	I	I	95	-	-	-	60/80	-	-	-	-
1/5/80	115	-	61	-	I	I	220	-	-	-	-	-	-	-	-
1/10/80	53	0.05	19	<0.2	I	I	14	30	-	-	20/30	12	-	-	-
1/13/80	28	0.8	111	67.2	3.4	<0.05	14	-	-	-	40/60	17	-	-	-

I = Interference

(continued)

APPENDIX B-2. (continued)

Table B-2. (continued)

Date	Suspended solids, mg/l	Phenol, mg/l	Ammonia, mg/l	Sulfide, mg/l	Cyanide$_T$, mg/l	Cyanide$_A$, mg/l	Polar organics, mg/l	Total Kjeldahl nitrogen, mg/l	Total dissolved solids, mg/l	Chlorides, mg/l	Color APHA units	Oil & grease, mg/l	Nitrate/nitrite-N, mg/l	BOD, mg/l	TOC, mg/l
Activated Carbon Effluent (continued)															
02/12/79	7	0.20	8	<0.2	0.2	<0.05	<1	12	21,000	8,750	200	-	0.0	-	73
02/13/79	11	0.6	3	<0.2	0.3	<0.05	3	-	-	-	-	-	-	-	64
02/14/79	13	<0.05	7	<0.2	1.2	1.1	2	16	15,300	2,870	25	12	6.8	164	89
02/15/79	7	2.1	6	<0.2	4.6	0.9	10	-	-	-	-	-	-	-	120
02/16/79	10	0.1	7	<0.2	10.6	2.8	15	-	17,000	-	-	-	6.6	-	110
02/19/79	12	1.1	7	<0.2	2.4	0.2	8	-	-	-	-	-	-	-	105
02/20/79	8	0.8	9	<0.2	0.4	1.6	<1	-	-	-	5/10	-	-	-	230
Bisulfite Dechlorination Tank															
6/5/80	23	-	-	-	-	-	-	-	-	-	200/250	-	-	-	-
6/5/80	84	-	-	-	-	-	-	-	-	-	-	-	-	-	-
6/5/80	84	-	-	-	-	-	-	-	-	-	60/20	-	-	-	-
6/5/80	124	-	-	-	-	-	-	-	-	-	-	-	-	-	-
6/10/80	78	-	-	-	-	-	-	-	-	-	-	-	-	-	-
6/11/80	860	-	-	-	-	-	<1	-	-	-	-	17	-	-	-
6/12/80	29	-	-	-	-	-	-	-	-	-	200/400	-	-	-	-
6/15/80	53	-	-	-	-	-	-	-	-	-	150/200	-	-	-	-
6/16/80	43	-	-	-	-	-	-	-	-	-	50/75	17	-	-	-
6/17/80	37	-	-	-	-	-	-	-	-	-	-	-	-	-	-
6/17/80	18	-	-	-	-	-	-	-	-	-	-	-	-	-	-

APPENDIX B-3

Contract 68-02-2685
Technical Directive 106, Change 1

SATS
PRIORITY POLLUTANT ANALYSIS OF COKE PLANT WASTES AND PILOT TREATMENT PLANT PROCESS STREAMS

Draft Report
Technical Directive 106, Change 1

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SORI-EAS-80-647

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I. Introduction

SATS
PRIORITY POLLUTANT ANALYSIS OF COKE PLANT WASTES AND PILOT TREATMENT PLANT PROCESS STREAMS

The purpose of this contract was to summarize and prepare a report on the analytical work performed on samples obtained under Directive 107 for EPA's Mobile Wastewater Treatment System (MWWTS) at the Shenango, Inc. by-product coke plant in Neville Island, Pennsylvania.

A total of 63 samples plus appropriate blanks were collected during the months of December 1979 and January 1980. The samples were shipped to Acurex, Mountain View, California, for analyses of organic priority pollutants and to Battelle Columbus Laboratories for metal priority pollutant analysis. Sampling was conducted in accordance with the EPA screening protocol.

Samples were collected during two phases of operation. During Phase I the MWWTS was treating coke plant waste in a mode consisting of chlorination, filtration, and activated carbon adsorption. During Phase II the carbon adsorption unit was replaced by a chemical dechlorination operation.

A site reference sampling code for samples taken during Phase I (December 1979) and Phase II (January 1980) is given in Table 1A and Table 1B along with a schematic of the MWWTS.

The priority pollutant sampling program was conducted by Davis and Floyd Engineers, Inc., Greenwood, South Carolina under subcontract to SoRI.

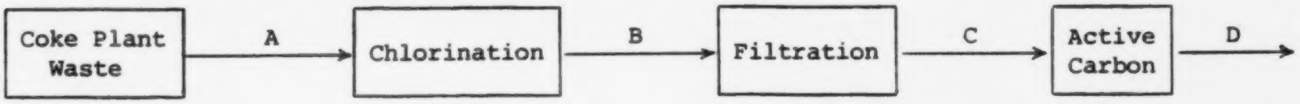
A summary of the verification report for Phase I Data and Phase II Data is presented in Tables 2 through 13 and Tables 14 through 25, respectively. The quality assurance summary for Phase I Data and Phase II Data is presented in Tables 26 through 33 and Tables 34 through 41, respectively. The quality assurance data summaries contain listings of all compounds that were determined with the following information about each compound.

- Concentration of spiked samples, µg/L
- Spike level, µg/L
- Mean concentration of unspiked samples, µg/L
- Percent recovery

The notations in the tables are those reported by Acurex. A few isolated data points were not included in this report because either they were unavailable or were illegible from the raw analytical data.

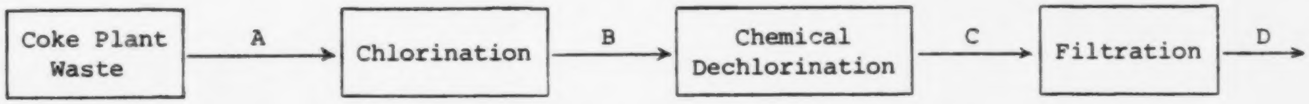
Critical review of the data reported in the quality assurance summaries for the organics suggested a few inconsistencies in the results. For example, there are incidents in which spiking levels were not high enough to be above the lower limits of detection. Also, a few data points were outside of the linear range of calibration. In those situations dilutions of the samples were apparently made and the results were incorporated in the data tables.

Table 1A. Phase I
Site Reference and Sampling Code


Coke Plant Waste
A
Chlorination
B
Filtration
C
Active Carbon
D

Date	Site A	Site B	Site C	Site D
12-4-79	06102	06103	06104	06105
12-5-79	06106	06107	06108	06109
12-6-79	06110	06111	06112	06113
12-7-79		06114	06115	06116
12-10-79	06117	06118	06119	06120
12-11-79		06121	06122	06123
12-12-79	06124	06125	06126	06127
12-13-79		06128	06129	06130
12-17-79	06134	06135	06136	06137
12-18-79		06138	06139	06140
12-19-79	06141	06142	06143	06144
12-20-79		06145	06146	06147

Table 1B. Phase II
Site Reference and Sampling Code


Coke Plant Waste
A
Chlorination
B
Chemical Dechlorination
C
Filtration
D

Date	Site A	Site B	Site C	Site D
1-7-80	06150	06151	06152	06153
1-8-80			06154	
1-10-80	06155	06156	06157	06158
1-11-80				06159
1-14-80	06166	06167	06168	06169
1-15-80				06170
1-16-80	06171	06172	06173	06174
1-17-80				06175

II. Verification Report

A. Phase I Data

1. Raw Waste Influent -- Site A

Table 2. GC/MS Verification Report for Volatile Organics
Phase I Data

Raw Waste Influent
Site A

Compounds	Concentration, µg/L						
	Week 1			Week 2		Week 3	
	12-4-79 06102	12-5-79 06106	12-6-79 06111	12-10-79 06117	12-12-79 06124	12-17-79 06134	12-19-79 06141
Chloroform (N)	*	—	12	—	16	8	12
(P)	170	—		*		—	
Benzene (N)	5900*	—	8200	—	7000	17000	19000
(P)	5500*	—	—	4200	—	—	—
Acrylonitrile (N)	4900	—	4400	—	1600	3900	7400
(P)	5200	—	—	1400	—	—	—
Dichlorobromomethane (N)		—	19	—	*	14	10
(P)	36	—	—	ND	—	—	—
Dibromochloromethane (N)	ND	—	ND	—	ND	ND	ND
(P)	ND	—	—	ND	—	—	—
Carbon tetrachloride (N)	—	—	ND	—	—	ND	ND
(P)	—	—	—	—	—	—	—
1,2-Dichloroethane (N)	—	—	ND	—	ND	ND	ND
(P)	—	—	—	—	—	—	—
trans-1,2-Dichloroethlene (N)	—	—	ND	—	—	ND	ND
(P)	—	—	—	—	—	—	—
Toluene (N)	1200	—	1600	—	1400	2400	2800
(P)	1340	—	—	1300	—	—	—
Chlorobenzene (N)	ND	—	ND	—	ND	ND	ND
(P)	ND	—	—	ND	—	—	—
Bromoform (N)	—	—	ND	—	*	ND	ND
(P)	—	—	—	—	—	—	—
Ethylbenzene (N)	*	—	ND	—	*	6	4
(P)	*	—	—	*	—	—	—
1,1,2,2-Tetrachloroethane (N)	—	—	ND	—	—	—	—
(P)	—	—	—	—	—	—	—
1,1-Dichloroethane (N)	—	—	ND	—	—	—	—
(P)	—	—	—	—	—	—	—

(N) - Unpreserved sample
(P) - Preserved sample
ND - Not detected
*Unknown notation from Acurex

Table 3 . GC/MS Verification Report for Semivolatile Organics
Phase I Data

Raw Waste Influent
Site A

Compounds	Concentration, µg/L						
	Week 1			Week 2		Week 3	
	12-4-79 06102	12-5-79 06106	12-6-79 06110	12-10-79 06117	12-12-79 06124	12-17-79 06134	12-19-79 06141
Naphthalene	1400	-	3400	1900	1600	1400	2800
Isophorone	ND	-	ND	ND	ND	ND	ND
2,4-Dinitrotoluene	ND	-	ND	ND	ND	ND	ND
Acenaphthylene	128	-	220	190	180	190	250
Acenaphthene	*	-	25	17	12	11	16
Fluorene	21	-	28	23	27	34	62
Phenanthrene/anthracene	64	-	93	70	100	72	120
Fluoranthene	13	-	13	10	ND	12	14
Chrysene/benzo(a)anthracene	23	-	22	18	40	28	26
Pyrene	11	-	12	*	16	9	13
Benzo(a)pyrene	14	-	17	14	29	29	20
Benzo(jk)fluoranthene	13	-	15	13	27	25	18
Benzo(ghi)perylene	*	-	*	*	12	32	7
Dibenzo(ah)anthracene	ND	-	ND	ND	ND	ND	ND
Indeno(1,2,3-cd)pyrene	*	-	*	*	12	19	4
Hexachlorobenzene	-	-	ND	-	ND	-	ND
Phenol	3200	-	2700	2400	3600	2800	6200
4-Chloro-m-cresol	ND	-	ND	ND	ND	ND	ND
2,4-Dimethylphenol	940	-	1000	1000	1100	1000	200
Pentachlorophenol	ND	-	ND	ND	ND	ND	ND
2-Chlorophenol	ND	-	ND	ND	ND	ND	ND
2,4-Dichlorophenol	ND	-	ND	ND	ND	ND	ND
2,4,6-Trichlorophenol	ND	-	ND	ND	ND	ND	ND

ND - Not detected
*Unknown notation from Acurex

Table 4 . Verification Report for Metals
Phase I Data

Raw Waste Influent
Site A

	Concentration, µg/L						
	Week 1			Week 2		Week 3	
Metals	12-4-79 06102	12-5-79 06106	12-6-79 06110	12-10-79 06117	12-12-79 06124	12-17-79 06134	12-19-79 06141
Calcium	15830	-	16080	15370	17800	17400	18200
Magnesium	4000	-	4230	3900	3930	4930	4590
Sodium	9.09×10^5	-	7.54×10^5	1.34×10^6	1.37×10^6	1.55×10^6	1.45×10^6
Aluminum	960	-	3100	585	795	4570	1330
Manganese	260	-	1180	205	300	1760	340
Lead	<50	-	<50	<250	<250	<250	<250
Vanadium	<5	-	9	<25	<25	<25	<25
Boron	580	-	590	250	300	530	620
Barium	41	-	58	35	38	59	41
Beryllium	<1	-	<1	<5	<5	<5	6.5
Cadmium	<5	-	6	<25	<25	<25	<25
Molybdenum	<10	-	<10	<50	<50	<50	<50
Tin	<10	-	<10	<100	<100	<100	<100
Yttrium	<5	-	<5	<25	<25	<25	<25
Cobalt	<5	-	<5	<25	<25	<25	<25
Chromium	15	-	52	<50	110	64	<50
Copper	34	-	35	<50	<50	54	<50
Iron	5470	-	9600	2890	3840	6480	2180
Nickel	<50	-	<50	<250	<250	<250	<250
Titanium	16	-	95	<25	<25	140	35
Zinc	360	-	130	<100	<100	190	<100
Selenium	200	-	170	225	230	152	382
Thallium	<3	-	<3	<15	<15	<15	<15
Silver	<1	-	<1	<2	<2	<2	<2
Arsenic	68	-	99	107	76	52	14
Antimony	<30	-	<30	<25	<25	<25	<25
Mercury	5.0	-	12	3.4	4.2	15	5.9

2. Chlorination Effluent -- Site B

Table 5. GC/MS Verification Report for Volatile Organics
Phase I Data

Chlorination Effluent
Site B

Compounds	Concentration, µg/L											
	Week 1				Week 2				Week 3			
	12-4-79 06103	12-5-79 06107	12-6-79 06111	12-7-79 06119	12-10-79 06118	12-11-79 06121	12-12-79 06125	12-13-79 06128	12-17-79 06135	12-18-79 06138	12-19-79 06142	12-20-79 06145
Chloroform (N)	5555*	6600*	9000	–	7400	–	–	5800	22100	24700	22000	30000
(P)	5735*	5600	–	7400	7900	4400	3700	–	–	–	–	–
Benzene (N)	3462*	3500*	3200	–	3500	–	–	3500	6800	5300	5000	4000
(P)	3967*	3300*	–	3400	3700	3200	2900	–	–	–	–	–
Acrylonitrile (N)	4300	4300	3300	–	990	–	–	3400	1600	1500	2100	960
(P)	4870	3900	–	3300	53	2400	970	–	–	–	–	–
Dichlorobromomethane (N)	2891*	2300	1700	–	4400	–	–	3700	3400	3000	3000	1800
(P)	2948*	2000	–	4900	4400	2300	2600	–	–	–	–	–
Dibromochloromethane (N)	674	420	360	–	1400	–	–	770	760	660	680	370
(P)	716	350	–	1900	1200	330	280	–	–	–	–	–
Carbon tetrachloride (N)	70	41	16	–	58	–	–	34	59	63	50	43
(P)	ND	37	–	78	66	53	46	–	–	–	–	–
1,2-Dichloroethane (N)	68	35	46	–	59	–	–	33	21	15	16	19
(P)	ND	33	–	84	62	*	*	–	–	–	–	–
trans-1,2-Dichloroethlene (N)	*	–	ND	–	–	–	–	–	ND	ND	ND	ND
(P)	ND	*	–	–	–	–	–	–	–	–	–	–
Toluene (N)	221	370	280	–	400	–	–	160	450	1400	540	1200
(P)	182	330	–	350	520	210	260	–	–	–	–	–
Chlorobenzene (N)	51	37	38	–	91	–	–	24	109	92	72	130
(P)	52	32	–	77	94	47	45	–	–	–	–	–
Bromoform (N)	–	16	ND	–	34	–	–	–	34	30	28	ND
(P)	–	12	–	44	21	–	ND	–	–	–	–	–
Ethylbenzene (N)	–	*	–	–	–	–	–	–	ND	ND	ND	ND
(P)	–	*	–	–	–	–	–	–	–	–	–	–
1,1,2,2-Tetrachloroethane (N)	–	–	ND	–	–	–	–	–	–	–	–	–
(P)	–	–	–	–	–	–	–	–	–	–	–	–
1,1-Dichloroethane (N)	–	–	ND	–	–	–	–	–	–	–	–	–
(P)	–	–	–	–	–	–	–	–	–	–	–	–

(N) - Unpreserved sample
(P) - Preserved sample
ND - Not detected
*Unknown notation from Acurex

Table 6. GC/MS Verification Report for Semivolatile Organics
Phase I Data

Chlorination Effluent
Site B

Compounds	Concentration, µg/L											
	Week 1				Week 2				Week 3			
	12-4-79 06103	12-5-79 06107	12-6-79 06111	12-7-79 06114	12-10-79 06118	12-11-79 06121	12-12-79 06125	12-13-79 06128	12-17-79 06135	12-18-79 06138	12-19-79 06142	12-20-79 06145
Naphthalene	31	16	200	220	330	180	14	24	500	740	700	80
Isophorone	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
2,4-Dinitrotoluene	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Acenaphthylene	*	ND	*	*	5	8	4	2	11	8	14	3
Acenaphthene	*	ND	110	*	6	11	5	10	19	16	6	12
Fluorene	*	*	80	*	15	19	10	3	7	ND	23	4
Phenanthrene/anthracene	*	*	57	*	28	43	21	6	19	12	41	7
Fluoranthene	*	*	*	ND	6	10	7	2	ND	ND	7	2
Chrysene/benzo(a)anthracene	*	*	*	*	11	13	18	6	ND	ND	8	4
Pyrene	*	ND	*	ND	3	4	4	1	ND	ND	2	ND
Benzo(a)pyrene	*	*	*	*	5	5	11	4	ND	ND	6	2
Benzo(jk)fluoranthene	11	*	*	*	10	9	14	6	7	ND	11	3
Benzo(ghi)perylene	*	ND	ND	–	ND	ND	5	ND	ND	ND	3	ND
Dibenzo(ah)anthracene	ND	ND	ND	–	ND	ND	ND	ND	ND	ND	ND	ND
Indeno(1,2,3-cd)pyrene	*	ND	*	–	ND	ND	5	3	ND	ND	3	ND
Hexachlorobenzene	–	–	ND	–	–	–	ND	ND	–	–	ND	–
Phenol	*	*	*	ND	ND	ND	ND	ND	*	2	4	ND
4-Chloro-m-cresol	*	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
2,4-Dimethylphenol	*	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Pentachlorophenol	ND	ND	ND	ND	ND	ND	*	ND	ND	ND	ND	ND
2-Chlorophenol	20	ND	10	ND	14	ND	*	ND	ND	ND	ND	ND
2,4-Dichlorophenol	97	90	180	13	36	17	*	*	15	46	14	5
2,4,6-Trichlorophenol	15	20	54	79	11	76	64	38	39	ND	*	10

ND - Not detected
*Unknown notation from Acurex

Table 7 . Verification Report for Metals
Phase I Data

Chlorination Effluent
Site B

Concentration, µg/L

Metals	Week 1				Week 2				Week 3			
	12-4-79 06103	12-5-79 06107	12-6-79 06111	12-7-79 06114	12-10-79 06118	12-11-79 06121	12-12-79 06125	12-13-79 06128	12-17-79 06135	12-18-79 06138	12-19-79 06142	12-20-79 06145
Calcium	9760	10590	13860	11390	12500	14600	16900	14200	17000	16300	18000	18500
Magnesium	3470	3700	4330	3520	3570	3730	3830	4230	4530	4090	4600	4320
Sodium	9.18×10^6	5.96×10^6	4.77×10^6	5.87×10^6	5.73×10^6	7.13×10^6	7.34×10^6	7.43×10^6	6.12×10^6	6.45×10^6	6.71×10^6	1.14×10^7
Aluminum	1000	1350	2550	1270	670	990	990	790	4230	2600	1480	1200
Manganese	270	240	1100	330	240	300	310	320	1560	680	370	370
Lead	69	51	80	53	<250	<250	<250	<250	<250	<250	<250	<250
Vanadium	11	12	21	13	< 25	29	27	< 25	31	26	26	63
Boron	1550	1140	980	1430	1140	1010	1080	1230	940	1100	1170	1220
Barium	36	37	60	36	36	43	42	41	57	49	49	54
Beryllium	<1	<1	2.0	<1	<5	<5	<5	<5	<5	<5	5.0	<5
Cadmium	<5	<5	<5	<5	<25	<25	<25	<25	<25	36	<25	<25
Molybdenum	14	<10	11	<10	<50	<50	<50	53	<50	<50	<50	<50
Tin	<10	<10	<10	<10	<100	<100	<100	<100	<100	<100	<100	<100
Yttrium	<5	<5	<5	<5	<25	<25	<25	<25	<25	<25	<25	<25
Cobalt	11	10	14	10	<25	42	<25	<25	<25	57	30	59
Chromium	36	21	89	44	<50	<50	140	150	92	94	53	110
Copper	74	88	110	90	<50	<50	<50	<50	93	340	68	71
Iron	8320	4410	21840	6090	4700	4880	4310	4680	11300	6990	4830	22900
Nickel	70	53	77	57	<250	<250	<250	<250	<250	<250	<250	<250
Titanium	16	21	76	35	<25	31	33	25	120	74	45	43
Zinc	240	160	230	99	<100	<100	<100	<100	220	300	590	165
Selenium	430	220	190	260	208	206	203	195	261	265	317	208
Thallium	<15	<15	<15	<15	<15	<15	<15	<15	<15	<15	<15	25
Silver	<1	<1	<1	<1	<2	<2	<2	<2	<2	<2	<2	<2
Arsenic	240	99	110	160	92	102	76	85	94	80	65	79
Antimony	<30	<30	<30	<30	<25	<25	<25	<25	<25	<25	<25	56
Mercury	31	20	21	13	21	40	26	14	24	18	15	26

3. Filtration Effluent -- Site C

Table 8 . GC/MS Verification Report for Volatile Organics
Phase I Data

Filtration Effluent
Site C

Compounds	Concentration, µg/L											
	Week 1				Week 2				Week 3			
	12-4-79 06104	12-5-79 06108	12-6-79 06112	12-7-79 06115	12-10-79 06119	12-11-79 06122	12-12-79 06126	12-13-79 06129	12-17-79 06136	12-18-79 06139	12-19-79 06143	12-20-79 06146
Chloroform (N)	2400*	5500*	5200	–	8100	–	15000	13000	27400	29500	29000	67000
(P)	2500*	6000*	–	8200	8300	4300	–	–	–	–	–	–
Benzene (N)	1400	3200*	3400	–	3800	–	4000	3600	8700	5500	5300	12000
(P)	2100*	3200*	–	3800	3900	3200	–	–	–	–	–	–
Acrylonitrile (N)	2500	3400	1200	–	640	–	3400	8100	10200	11300	11000	2100
(P)	2700	4000	–	2100	2000	2200	–	–	–	–	–	–
Dichlorobromomethane (N)	1400	2400	1700	–	4600	–	3000	3500	3700	3300	3200	6400
(P)	2100*	2100	–	5700	4800	2700	–	–	–	–	–	–
Dibromochloromethane (N)	720	400	210	–	1400	–	360	780	920	740	770	810
(P)	1000	370	–	2300	1400	360	–	–	–	–	–	–
Carbon tetrachloride (N)	89	60	26	–	70	–	48	44	71	73	54	46
(P)	120	55	–	97	59	52	–	–	–	–	–	–
1,2-Dichloroethane (N)	68	33	19	–	62	–	ND	32	24	16	20	24
(P)	100	33	–	100	67	*	–	–	–	–	–	–
trans-1,2-Dichloroethlene (N)	13	–	ND	–	–	–	–	–	ND	ND	ND	ND
(P)	13	–	–	–	–	–	–	–	–	–	–	–
Toluene (N)	170	230	380	–	480	–	240	180	550	440	380	2000
(P)	200	250	–	340	460	220	–	–	–	–	–	–
Chlorobenzene (N)	76	23	44	–	99	–	42	28	102	85	88	110
(P)	82	25	–	79	98	49	–	–	–	–	–	–
Bromoform (N)	35	*	ND	–	30	–	ND	–	50	49	44	28
(P)	43	*	–	69	28	–	–	–	–	–	–	–
Ethylbenzene (N)	–	–	–	–	–	–	–	–	ND	ND	ND	ND
(P)	–	–	–	–	–	–	–	–	–	–	–	–
1,1,2,2-Tetrachloroethane (N)	*	–	ND	–	–	–	–	–	–	–	–	–
(P)	–	–	–	–	–	–	–	–	–	–	–	–
1,1-Dichloroethane (N)	*	–	*	–	–	–	–	–	–	–	–	–
(P)	–	–	–	–	–	–	–	–	–	–	–	–

(N) - Unpreserved sample
(P) - Preserved sample
ND - Not detected
*Unknown notation from Acurex

Table 9. GC/MS Verification Report for Semivolatile Organics
Phase I Data

Filtration Effluent
Site C

Compounds	Concentration, µg/L											
	Week 1				Week 2				Week 3			
	12-4-79 06104	12-5-79 06108	12-6-79 06112	12-7-79 06115	12-10-79 06119	12-11-79 06122	12-12-79 06126	12-13-79 06129	12-17-79 06136	12-18-79 06139	12-19-79 06143	12-20-79 06146
Naphthalene	264	21	140	240	240	190	160	35	640	370	960	410
Isophorone	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
2,4-Dinitrotoluene	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Acenaphthylene	ND	ND	*	*	ND	ND	ND	ND	8	ND	4	2
Acenaphthene	*	*	230	*	ND	5	6	10	ND	ND	12	10
Fluorene	*	*	250	*	7	9	5	4	7	ND	14	6
Phenanthrene/anthracene	15	*	62	*	9	15	8	4	22	ND	22	16
Fluoranthene	*	*	*	*	2	3	2	1	5	ND	4	1
Chrysene/benzo(a)anthracene	*	*	*	*	ND	2	4	ND	10	ND	4	ND
Pyrene	ND	ND	ND	ND	ND	ND	ND	ND	2	ND	ND	ND
Benzo(a)pyrene	*	ND	*	*	ND	ND	3	ND	9	ND	2	ND
Benzo(jk)fluoranthene	*	*	*	*	ND	2	4	2	11	ND	6	ND
Benzo(ghi)perylene	ND	ND	ND	ND	ND	ND	2	ND	ND	ND	ND	ND
Dibenzo(ah)anthracene	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Indeno(1,2,3-cd)pyrene	ND	ND	ND	ND	ND	ND	2	ND	4	ND	ND	ND
Hexachlorobenzene	-	-	ND	-	-	-	ND	-	-	-	ND	-
Phenol	*	ND	380	ND	ND	ND	ND	ND	ND	ND	3	ND
4-Chloro-m-cresol	*	ND	ND	ND	ND	ND	ND	ND	ND	ND	*	ND
2,4-Dimethylphenol	*	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Pentachlorophenol	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
2-Chlorophenol	*	*	ND	ND	ND	ND	ND	ND	12	5	ND	ND
2,4-Dichlorophenol	21	54	210	15	10	19	*	10	*	11	8	3
2,4,6-Trichlorophenol	*	17	84	66	56	86	60	42	44	-	25	19

ND - Not detected
*Unknown notation from Acurex

Table 10. Verification Report for Metals
Phase I Data

Filtration Effluent
Site C

	Concentration, µg/L											
	Week 1				Week 2				Week 3			
Metals	12-4-79 06104	12-5-79 06108	12-6-79 06112	12-7-79 06115	12-10-79 06119	12-11-79 06122	12-12-79 06126	12-13-79 06129	12-17-79 06136	12-18-79 06139	12-19-79 06143	12-20-79 06146
Calcium	9440	10610	18940	13290	13000	14900	16800	14200	16800	15800	17400	19200
Magnesium	3220	3700	5700	3760	3530	3730	3780	4270	4360	3950	4300	4260
Sodium	9.59×10^{6}	5.70×10^{6}	4.43×10^{6}	6.24×10^{6}	5.69×10^{6}	7.51×10^{6}	7.06×10^{6}	7.88×10^{6}	6.31×10^{6}	6.43×10^{6}	6.56×10^{6}	1.45×10^{7}
Aluminum	600	1050	4200	850	479	690	585	620	2690	1450	850	990
Manganese	180	190	1410	290	230	225	190	150	1140	350	230	190
Lead	<50	<50	210	<50	<250	<250	<250	<250	<250	<250	<250	<250
Vanadium	12	10	32	13	<25	26	25	<25	<25	29	<25	50
Boron	1550	1140	950	1450	1140	940	960	1310	1030	1080	1120	1220
Barium	32	34	83	36	36	41	39	40	43	35	40	64
Beryllium	<1	<1	1.8	<1	<5	<5	<5	<5	<5	<5	<5	<5
Cadmium	4	10	69	7	<25	<25	<25	<25	<25	<25	<25	25
Molybdenum	<10	<10	13	<10	<50	<50	<50	<50	<50	<50	<50	<50
Tin	<10	<10	<10	<10	<100	<100	<100	<100	<100	<100	<100	<100
Yttrium	<5	<5	<5	<5	<25	<25	<25	<25	<25	<25	<25	<25
Cobalt	10	12	16	11	<25	<25	<25	<25	<25	43	<25	56
Chromium	24	30	100	32	<50	<50	140	170	60	<50	<50	190
Copper	91	130	200	84	<50	59	<50	<50	82	160	72	230
Iron	6010	3690	34640	5500	3460	3360	2980	3450	8960	4990	3480	12200
Nickel	52	<50	98	50	<250	<250	<250	<250	<250	<250	<250	<250
Titanium	9	12	100	18	<25	<25	<25	<25	77	34	<25	28
Zinc	970	1210	1750	380	250	1100	2670	2890	770	640	840	2760
Selenium	470	220	170	240	216	188	202	202	235	258	318	174
Thallium	<15	<15	<15	<15	<15	<15	<15	<15	<15	<15	<15	70
Silver	<1	<1	<1	<1	<2	<2	<2	<2	<2	<2	<2	<2
Arsenic	260	85	180	110	96	51	40	57	77	67	48	41
Antimony	<30	<30	<30	<30	<25	<25	<25	<25	<25	<25	<25	<25
Mercury	30	20	22	10	19	37	26	16	21	16	14	28

4. Activated Carbon Effluent -- Site D

Table 11. GC/MS Verification Report for Volatile Organics
Phase I Data

Activated Carbon Effluent
Site D

Compounds	Week 1				Week 2				Week 3			
	12-4-79 06105	12-5-79 06109	12-6-79 06113	12-7-79 06116	12-10-79 06120	12-11-79 06123	12-12-79 06127	12-13-79 06130	12-17-79 06137	12-18-79 06140	12-19-79 06144	12-20-79 06147
Chloroform (N)	ND	ND	ND	20	9	-	-	17	830	630	2200	3200
(P)	*	-	-	-	18	*	*	-	-	-	-	-
Benzene (N)	ND	*	ND	33	23	-	-	13	ND	ND	ND	ND
(P)	*	*	-	-	27	19	27	-	-	-	-	-
Acrylonitrile (N)	ND	36	52	340	1300	-	-	8500	2800	3900	3600	3600
(P)	ND	36	-	-	760	2800	2500	-	-	-	-	-
Dichlorobromomethane (N)	-	ND*	ND	ND	ND	-	-	ND	ND	27	57	63
(P)	-	ND	-	-	ND	ND	ND	-	-	-	-	-
Dibromochloromethane (N)	-	ND	ND	ND	ND	-	-	ND	ND	ND	ND	ND
(P)	-	ND	-	-	ND	ND	ND	-	-	-	-	-
Carbon tetrachloride (N)	-	-	ND	-	-	-	-	-	ND	ND	ND	ND
(P)	-	-	-	-	-	-	ND	-	-	-	-	-
1,2-Dichloroethane (N)	-	-	ND	-	-	-	-	-	19	28	40	64
(P)	-	-	-	-	-	-	ND	-	-	-	-	-
trans-1,2-Dichloroethlene (N)	-	-	ND	-	-	-	-	-	ND	ND	ND	ND
(P)	-	-	-	-	-	-	-	-	-	-	-	-
Toluene (N)	ND	56	60	10	*	-	-	*	ND	ND	ND	ND
(P)	*	56	-	-	*	11	*	-	-	-	-	-
Chlorobenzene (N)	-	ND	ND	-	ND	-	-	ND	ND	ND	ND	ND
(P)	-	ND	-	-	ND	*	ND	-	-	-	-	-
Bromoform (N)	-	-	ND	-	-	-	-	-	-	-	ND	ND
(P)	-	-	-	-	-	-	ND	-	-	-	-	-
Ethylbenzene (N)	-	-	-	-	-	-	-	ND	ND	ND	ND	ND
(P)	-	-	-	-	-	*	ND	-	-	-	-	-
1,1,2,2-Tetrachloroethane (N)	-	-	ND	-	-	-	-	-	-	-	-	-
(P)	-	-	-	-	-	-	-	-	-	-	-	-
1,1-Dichloroethane (N)	-	-	ND	-	-	-	-	-	-	-	-	-
(P)	-	-	-	-	-	-	-	-	-	-	-	-

(N) - Unpreserved sample
(P) - Preserved sample
ND - Not detected
*Unknown notation from Acurex

Table 12. GC/MS Verification Report for Semivolatile Organics
Phase I Data

Activated Carbon Effluent
Site D

Compounds	Concentration, µg/L											
	Week 1				Week 2				Week 3			
	12-4-79 06105	12-5-79 06109	12-6-79 06113	12-7-79 06116	12-10-79 06120	12-11-79 06123	12-12-79 06127	12-13-79 06130	12-17-79 06137	12-18-79 06140	12-19-79 06144	12-20-79 06147
Naphthalene	ND	ND	ND	*	*	ND	0.5	ND	9	2	2	ND
Isophorone	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
2,4-Dinitrotoluene	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Acenaphthylene	ND	ND	ND	ND	ND	ND	ND	ND	1	ND	ND	ND
Acenaphthene	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Fluorene	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Phenanthrene/anthracene	ND	ND	ND	ND	*	ND	ND	ND	3	ND	ND	ND
Fluoranthene	ND	ND	-	ND	ND	ND	ND	ND	ND	ND	ND	ND
Chrysene/benzo(a)anthracene	ND	ND	ND	-	ND	ND	ND	ND	ND	ND	ND	ND
Pyrene	ND	ND	ND	-	ND	ND	ND	ND	ND	ND	ND	ND
Benzo(a)pyrene	ND	ND	ND	-	ND	ND	ND	ND	ND	ND	ND	ND
Benzo(jk)fluoranthene	ND	ND	-	-	ND	ND	ND	ND	ND	ND	ND	ND
Benzo(ghi)perylene	ND	ND	ND	-	ND	ND	ND	ND	ND	ND	ND	ND
Dibenzo(ah)anthracene	ND	ND	-	-	ND	ND	ND	ND	ND	ND	ND	ND
Indeno(1,2,3-cd)pyrene	ND	ND	ND	-	ND	ND	ND	ND	ND	ND	ND	ND
Hexachlorobenzene	-	-	ND	-	ND	ND	ND	ND	-	-	ND	-
Phenol	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
4-Chloro-m-cresol	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
2,4-Dimethylphenol	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Pentachlorophenol	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
2-Chlorophenol	-	-	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
2,4-Dichlorophenol	-	-	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
2,4,6-Trichlorophenol	-	-	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND

ND - Not detected
*Unknown notation from Acurex

Table 13. Verification Report for Metals
Phase I Data

Activated Carbon Effluent
Site D

Metals	Week 1				Week 2				Week 3			
	Concentration, µg/L											
	12-4-79 06105	12-5-79 06109	12-6-79 06113	12-7-79 06116	12-10-79 06120	12-11-79 06123	12-12-79 06127	12-13-79 06130	12-17-79 06137	12-18-79 06140	12-19-79 06144	12-20-79 06147
Calcium	16500	11340	11950	15480	11800	15400	16600	17700	15800	15900	16200	20500
Magnesium	3870	3930	4100	3580	3750	3800	4200	4990	4400	4130	4040	4680
Sodium	8.03×10^6	6.05×10^6	3.90×10^6	5.89×10^6	6.42×10^6	7.25×10^6	7.27×10^6	6.51×10^6	6.2×10^6	5.79×10^6	6.66×10^6	7.03×10^6
Aluminum	1920	1370	820	1220	1770	1340	1100	1680	1710	960	1140	920
Manganese	500	260	190	320	380	280	240	260	340	570	430	340
Lead	<50	62	<50	85	<250	<250	<250	<250	<250	<250	<250	<250
Vanadium	30	19	18	28	42	29	31	27	30	30	42	43
Boron	1780	1190	820	760	760	1530	810	1140	800	1070	1140	970
Barium	120	61	44	55	71	94	90	95	76	50	55	70
Beryllium	<1	<1	<1	<1	<5	<5	<5	<5	<5	<5	<5	<5
Cadmium	11	16	43	13	90	<25	<25	<25	<25	<25	<25	<25
Molybdenum	13	<10	<10	<10	<50	<50	<50	<50	<50	<50	<50	<50
Tin	<10	<10	<10	<10	<100	<100	<100	<100	<100	<100	<100	<100
Yttrium	5	<5	<5	<5	<25	<25	<25	27	<25	<25	<25	<25
Cobalt	21	14	14	16	43	30	25	<25	<25	35	43	46
Chromium	16	22	27	12	<50	<50	680	114	<50	<50	<50	<50
Copper	15	22	13	26	84	<50	<50	<50	<50	65	<50	<50
Iron	2870	2390	2210	4160	7740	1680	3140	910	5420	3380	2200	4610
Nickel	60	75	54	<50	<250	<250	<250	<250	<250	<250	<250	<250
Titanium	8	8	10	15	46	<25	<25	<25	34	<25	<25	<25
Zinc	88	97	220	110	220	<100	<100	<100	140	120	<100	<100
Selenium	345	210	130	240	216	207	209	210	260	281	306	241
Thallium	<15	<15	<15	<15	<15	<15	<15	<15	<15	<15	<15	<15
Silver	<1	<1	<1	<1	<2	<2	<2	<2	<2	<2	<2	<2
Arsenic	220	99	<60	87	103	34	42	41	50	55	48	33
Antimony	<30	<30	<30	<30	<25	<25	<25	<25	<25	<25	63	<25
Mercury	<0.3	<0.3	0.7	1.1	1.3	2.6	2.3	1.1	3.8	3.7	5.3	6.1

II. Verification Report

B. Phase II Data

1. Raw Waste Influent -- Site A

Table 14. GC/MS Verification Report for Volatile Organics
Phase II Data

Raw Waste Influent
Site A

Compounds	Concentration, µg/L			
	Week 1		Week 2	
	1-7-80 06150	1-10-80 06155	1-14-80 06166	1-16-80 06171
Chloroform	15	7	18	22
Benzene	15500	1045	5200	4380
Acrylonitrile	2100	980	19300	13700
Dichlorobromomethane	ND	-	8	16
Dibromochloromethane	ND	ND	ND	ND
Carbon tetrachloride	ND	ND	ND	ND
1,2-Dichloroethane	ND	ND	ND	ND
trans-1,2-Dichloroethylene	ND	ND	ND	ND
Toluene	2100	458	2660	2600
Chlorobenzene	ND	ND	ND	ND
Bromoform	ND	ND	ND	ND
Ethylbenzene	5	6	ND	8

ND - Not detected

Table 15. GC/MS Verification Report for Semivolatile Organics
Phase II Data

Raw Waste Influent
Site A

	Concentration, µg/L			
	Week 1		Week 2	
Compounds	1-7-80 06150	1-10-80 06155	1-14-80 06166	1-16-80 06171
Naphthalene	2100	2250	3600	1700
Isophorone	ND	ND	ND	ND
2,4-Dinitrotoluene	ND	ND	ND	ND
Acenaphthylene	220	225	410	280
Acenaphthene	19	30	21	18
Fluorene	57	49	48	45
Phenanthrene/anthracene	260	275	150	150
Fluoranthene	73	63	41	36
Chrysene/benzo(a)anthracene	29	52	26	48
Pyrene	54	50	31	28
Benzo(a)pyrene	22	38	29	22
Benzo(jk)fluoranthene	26	50	30	33
Benzo(ghi)perylene	9	28	6	5
Dibenzo(ah)anthracene	ND	10	ND	ND
Indeno(1,2,3-cd)pyrene	9	28	10	8
Hexachlorobenzene	-	ND	-	-
Phenol	5300	3705	3820	4950
4-Chloro-m-cresol	ND	ND	ND	ND
2,4-Dimethylphenol	2490	1990	2280	2650
Pentachlorophenol	ND	ND	ND	ND
2-Chlorophenol	ND	ND	ND	ND
2,4-Dichlorophenol	ND	ND	ND	ND
2,4,6-Trichlorophenol	ND	ND	ND	ND

ND - Not detected

Table 16. Verification Report for Metals
Phase II Data

Raw Waste Influent
Site A

Metals	Concentration, µg/L			
	Week 1		Week 2	
	1-7-80 06150	1-10-80 06155	1-14-80 06166	1-16-80 06171
Calcium	18800	21300	19000	15400
Magnesium	4520	4730	4500	5090
Sodium	1.24×10^6	2.07×10^6	5.36×10^5	1.16×10^6
Aluminum	740	1340	700	1030
Manganese	180	410	240	180
Lead	<250	<250	<250	<250
Vanadium	<25	<25	<25	<25
Boron	720	740	290	770
Barium	36	44	38	36
Beryllium	<5	<5	<5	<5
Cadmium	<25	<25	<25	<25
Molybdenum	<50	<50	<50	<50
Tin	<50	<50	<50	<50
Yttrium	<25	<25	<25	<25
Cobalt	<25	<25	<25	<25
Chromium	<50	<50	<50	<50
Copper	<50	<50	<50	<50
Iron	2780	12200	2520	2220
Nickel	<250	<250	<250	<250
Titanium	<25	39	<25	<25
Zinc	<50	52	<50	<50
Selenium	21	17	46	110
Thallium	<50	<50	<50	<50
Silver	<2	<2	<2	<2
Arsenic	50	74	46	51
Antimony	<100	<100	<100	<100
Mercury	5.1	8.6	7.8	1.4

2. Chlorination Effluent -- Site B

Table 17 GC/MS Verification Report for Volatile Organics
Phase II Data

Chlorination Effluent
Site B

	Concentration, µg/L			
	Week 1		Week 2	
Compounds	1-7-80 06151	1-10-80 06156	1-14-80 06167	1-16-80 06172
Chloroform	25000	11000	42000	42500
Benzene	4200	395	10000	7050
Acrylonitrile	1300	415	1500	600
Dichlorobromomethane	1300	915	1900	3470
Dibromochloromethane	1000	730	200	1050
Carbon tetrachloride	42	ND	280	290
1,2-Dichloroethane	44	11	48	28
trans-1,2-Dichloroethylene	ND	ND	ND	ND
Toluene	180	350	610	730
Chlorobenzene	320	205	58	48
Bromoform	210	685	ND	26
Ethylbenzene	ND	ND	ND	ND

ND - Not detected

Table 18. GC/MS Verification Report for Semivolatile Organics
Phase II Data

Chlorination Effluent
Site B

	Concentration, µg/L			
	Week 1		Week 2	
	1-7-80	1-10-80	1-14-80	1-16-80
Compounds	06151	06156	06167	06172
Naphthalene	250	23	290	268
Isophorone	ND	ND	ND	ND
2,4-Dinitrotoluene	ND	ND	ND	ND
Acenaphthylene	3	6	19	14
Acenaphthene	14	17	25	48
Fluorene	17	2	21	42
Phenanthrene/anthracene	28	15	45	80
Fluoranthene	11	6	18	51
Chrysene/benzo(a)anthracene	5	7	18	54
Pyrene	4	3	6	10
Benzo(a)pyrene	ND	4	6	8
Benzo(jk)fluoranthene	5	9	19	60
Benzo(ghi)perylene	ND	ND	ND	13
Dibenzo(ah)anthracene	ND	ND	ND	ND
Indeno(1,2,3-cd)pyrene	ND	2	3	22
Hexachlorobenzene	ND	-	-	ND
Phenol	290	51	8	4
4-Chloro-m-cresol	ND	ND	ND	ND
2,4-Dimethylphenol	12	13	ND	ND
Pentachlorophenol	ND	ND	ND	ND
2-Chlorophenol	ND	23	21	11
2,4-Dichlorophenol	10	ND	70	64
2,4,6-Trichlorophenol	ND	ND	61	64

ND - Not detected

Table 19. Verification Report for Metals Phase II Data

Chlorination Effluent
Site B

	Concentration, µg/L			
	Week 1		Week 2	
	1-7-80	1-10-80	1-14-80	1-16-80
Metals	06151	06156	06167	06172
Calcium	17200	14800	17300	14000
Magnesium	3950	3520	4010	3490
Sodium	1.07×10^7	2.15×10^7	6.00×10^6	6.96×10^6
Aluminum	840	1170	790	1100
Manganese	260	370	300	260
Lead	<250	320	<250	<250
Vanadium	29	50	<25	<25
Boron	1030	2020	870	1420
Barium	43	42	39	41
Beryllium	<5	<5	<5	<5
Cadmium	<25	<25	<25	<25
Molybdenum	<50	50	<50	<50
Tin	<50	58	<50	<50
Yttrium	<25	<25	<25	<25
Cobalt	33	45	<25	<25
Chromium	<50	79	<50	<50
Copper	<50	120	<50	<50
Iron	9920	13700	5060	4750
Nickel	<250	<250	<250	<250
Titanium	36	41	30	28
Zinc	80	170	100	140
Selenium	84	79	66	130
Thallium	<50	<250	<50	<50
Silver	2.7	2.7	<2	<2
Arsenic	27	62	38	63
Antimony	<100	<100	<100	<100
Mercury	28	30	11	15

3. Chemical Dechlorination Effluent -- Site C

Table 20. GC/MS Verification Report for Volatile Organics
Phase II Data

Chemical Dechlorination Effluent
Site C

	Concentration, µg/L				
	Week 1			Week 2	
Compounds	1-7-80 06152	1-10-80 06154	1-10-80 06157	1-14-80 06166	1-16-80 06171
Chloroform	21000	22000	7000	37000	37900
Benzene	2000	1960	115	3800	5710
Acrylonitrile	1000	630	235	1500	470
Dichlorobromomethane	900	1400	785	1700	2770
Dibromochloromethane	530	360	590	170	795
Carbon tetrachloride	31	32	ND	220	200
1,2-Dichloroethane	36	46	10	41	9
trans-1,2-Dichloroethylene	ND	ND	ND	ND	ND
Toluene	150	320	290	500	620
Chlorobenzene	270	210	130	44	42
Bromoform	100	32	410	ND	31
Ethylbenzene	ND	ND	ND	ND	ND

ND - Not detected

Table 21. GC/MS Verification Report for Semivolatile Organics
Phase II Data

Chemical Dechlorination Effluent
Site C

	Concentration, μg/L				
	Week 1			Week 2	
	1-7-80	1-8-80	1-10-80	1-14-80	1-16-80
Compounds	06152	06154	06157	06168	06173
Naphthalene	94	7	88	570	340
Isophorone	ND	ND	ND	ND	ND
2,4-Dinitrotoluene	ND	ND	ND	ND	ND
Acenaphthylene	4	1	6	27	48
Acenaphthene	13	1	7	36	56
Fluorene	21	1	7	29	71
Phenanthrene/anthracene	31	3	33	63	121
Fluoranthene	18	5	15	25	33
Chrysene/benzo(a)anthracene	12	7	25	26	85
Pyrene	5	1	8	10	32
Benzo(a)pyrene	4	3	2	5	15
Benzo(jk)fluoranthene	12	8	20	26	50
Benzo(ghi)perylene	ND	3	2	ND	10
Dibenzo(ah)anthracene	ND	ND	ND	ND	ND
Indeno(1,2,3-cd)pyrene	ND	3	2	5	14
Hexachlorobenzene	-	-	ND	-	-
Phenol	170	15	7	11	18
4-Chloro-m-cresol	ND	ND	ND	ND	ND
2,4-Dimethylphenol	9	ND	ND	6	8
Pentachlorophenol	ND	ND	ND	ND	ND
2-Chlorophenol	36	56	10	26	22
2,4-Dichlorophenol	11	2	2	82	54
2,4,6-Trichlorophenol	ND	ND	ND	75	61

ND - Not detected

Table 22. Verification Report for Metals
Phase II Data

Chemical Dechlorination Effluent
Site C

	Concentration, µg/L				
	Week 1			Week 2	
	1-7-80	1-8-80	1-10-80	1-14-80	1-16-80
Metals	06152	06154	06157	06168	06173
Calcium	16600	19300	15400	17800	14300
Magnesium	3810	4430	3850	4050	3590
Sodium	1.07x10^{7}	1.51x10^{7}	2.19x10^{7}	6.36x10^{6}	6.99x10^{6}
Aluminum	720	1390	1740	900	1090
Manganese	260	420	450	340	250
Lead	<250	<250	310	<250	<250
Vanadium	28	29	46	<25	<25
Boron	1010	1130	2250	1010	1330
Barium	41	48	54	40	48
Beryllium	<5	<5	7	<5	10
Cadmium	<25	<25	<25	<25	<25
Molybdenum	<50	<50	64	<50	<50
Tin	<50	<50	87	<50	55
Yttrium	<25	<25	<25	<25	<25
Cobalt	41	32	43	<25	<25
Chromium	<50	140	120	<50	<50
Copper	75	<50	130	<50	<50
Iron	9230	21700	19900	5920	4820
Nickel	<250	<250	<250	<250	<250
Titanium	27	48	58	26	37
Zinc	160	160	200	130	200
Selenium	82	60	110	57	120
Thallium	<50	<100	<250	<50	<50
Silver	2.2	2.6	2.7	<2	<2
Arsenic	29	25	57	33	48
Antimony	<100	<100	<100	<100	<100
Mercury	28	34	32	11	14

4. Filtration Effluent -- Site D

Table 23 GC/MS Verification Report for Volatile Organics
Phase II Data

Filtration Effluent
Site D

Compounds	Concentration, µg/L						
	Week 1			Week 2			
	1-7-80 06153	1-10-80 06158	1-11-80 06159	1-14-80 06169	1-15-80 06170	1-16-80 06174	1-17-80 06175
Chloroform	22000	7050	9100	38000	35200	30000	40300
Benzene	3900	125	360	7800	5540	6020	6600
Acrylonitrile	1100	215	4	1040	930	520	650
Dichlorobromomethane	970	885	380	1720	2600	3600	2980
Dibromochloromethane	630	935	190	200	780	1030	940
Carbon tetrachloride	26	ND	61	220	210	300	240
1,2-Dichloroethane	41	13	10	28	38	23	18
trans-1,2-Dichloroethylene	5	ND	ND	ND	ND	ND	ND
Toluene	210	10	22	540	370	510	580
Chlorobenzene	291	170	96	52	109	42	51
Bromoform	160	650	20	ND	81	36	52
Ethylbenzene	ND	ND	ND	ND	ND	ND	ND

ND - Not detected

Table 24. GC/MS Verification Report for Semivolatile Organics
Phase II Data

Filtration Effluent
Site D

	Concentration, µg/L						
	Week 1			Week 2			
Compounds	1-7-80 06153	1-10-80 06158	1-11-80 06159	1-14-80 06169	1-15-80 06170	1-16-80 06174	1-17-80 06175
Naphthalene	120	126	82	890	1300	274	166
Isophorone	ND	ND	ND	ND	ND	ND	ND
2,4-Dinitrotoluene	ND	ND	ND	ND	ND	ND	ND
Acenaphthylene	7	2	ND	3	ND	2	ND
Acenaphthene	12	9	ND	ND	ND	ND	ND
Fluorene	23	2	ND	5	5	6	5
Phenanthrene/anthracene	53	4	ND	7	10	8	8
Fluoranthene	32	1	ND	ND	ND	1	2
Chrysene/benzo(a)anthracene	21	-	ND	ND	ND	ND	10
Pyrene	11	-	ND	ND	ND	ND	2
Benzo(a)pyrene	6	ND	ND	ND	ND	ND	ND
Benzo(jk)fluoranthene	17	ND	ND	ND	ND	ND	ND
Benzo(ghi)perylene	ND	ND	ND	ND	ND	ND	ND
Dibenzo(ah)anthracene	ND	ND	ND	ND	ND	ND	ND
Indeno(1,2,3-cd)pyrene	3	ND	ND	ND	ND	ND	ND
Hexachlorobenzene	-	ND	-	-	-	ND	-
Phenol	120	410	8	10	15	18	11
4-Chloro-m-cresol	ND	ND	ND	ND	ND	ND	ND
2,4-Dimethylphenol	5	ND	ND	5	ND	6	4
Pentachlorophenol	ND	ND	ND	ND	ND	ND	ND
2-Chlorophenol	25	20	ND	27	17	22	16
2,4-Dichlorophenol	12	4	3	68	40	59	37
2,4,6-Trichlorophenol	ND	ND	ND	70	51	73	28

ND - Not detected

Table 25. Verification Report for Metals
Phase II Data

Filtration Effluent
Site D

Metals	Concentration, µg/L						
	Week 1			Week 2			
	1-7-80 06153	1-10-80 06158	1-11-80 06159	1-14-80 06169	1-15-80 06170	1-16-80 06174	1-17-80 06175
Calcium	17100	18700	19700	17100	15400	17800	13400
Magnesium	3410	3430	3500	3910	3670	3830	3520
Sodium	1.05×10^7	2.00×10^7	7.80×10^6	5.91×10^6	8.36×10^6	6.35×10^6	7.72×10^6
Aluminum	570	810	400	390	440	450	500
Manganese	240	280	810	250	250	200	1800
Lead	<250	<250	<250	<250	<250	<250	<250
Vanadium	<25	47	28	<25	<25	<25	<25
Boron	1170	1770	980	910	1350	1200	1400
Barium	39	49	37	35	37	44	35
Beryllium	<5	<5	<5	<5	<5	<5	<5
Cadmium	<25	<25	<25	25	<25	<25	<25
Molybdenum	<50	52	<50	<50	<50	<50	<50
Tin	<50	51	<50	<50	<50	<50	<50
Yttrium	<25	<25	<25	<25	<25	<25	<25
Cobalt	32	49	29	42	35	<25	<25
Chromium	<50	73	<50	<50	<50	<50	<50
Copper	61	150	<50	110	54	<50	<50
Iron	5890	2390	4150	3580	4120	2420	4500
Nickel	<250	<250	<250	<250	<25	<250	<250
Titanium	<25	<25	<25	<25	<25	<25	<25
Zinc	490	3800	980	490	480	110	90
Selenium	74	115	28	44	120	87	140
Thallium	<50	<250	<50	<50	<50	<50	<50
Silver	2.4	2.7	<2	<2	<2	<2	<2
Arsenic	<10	<10	<10	<10	49	24	37
Antimony	<100	<100	<100	<100	<100	<100	<100
Mercury	24	32	7.2	18	12	6.2	6.1

III. Quality Assurance Summary

A. Phase I Data

Table 26. GC/MS Verification Report
Quality Assurance Summary for Volatile Organics
Phase I Data

Raw Waste Influent

Compounds	Week 1				Week 2				Week 3			
	Concentration (µg/L)				Concentration (µg/L)				Concentration (µg/L)			
	Spiked	Mean Unspiked	Spike Level	Recovery %	Spiked	Mean Unspiked	Spike Level	Recovery %	Spiked	Mean Unspiked	Spike Level	Recovery %
Chloroform	100	12	200	44	102	16	100	86	75	12	100	63
Benzene	9700	8200	5000	30	7800	7000	5000	16	6000	5800	100	200
Acrylonitrile	4000	4400	-	-	8600	1600	5000	140	11500	7400	1000	410
Dichlorobromomethane	120	19	200	50	50	*	100	50	74	10	100	64
Dibromochloromethane	ND	ND	-	-	ND	ND	-	-	22	ND	100	22
Carbon tetrachloride	ND	ND	-	-	ND	ND	-	-	93	ND	100	93
1,2-Dichloroethane	ND	ND	-	-	ND	ND	-	-	138	ND	100	140
trans-1,2-Dichloroethylene	ND	ND	-	-			-	-	169	ND	100	170
Toluene	2400	1600	1500	53	2600	1400	2000	60	1840	2100	100	
Chlorobenzene	ND	ND	-	-	ND	ND	-	-	110	ND	100	110
Bromoform	ND	ND	-	-	ND	ND	-	-	5	ND	100	5
Ethylbenzene	ND	ND	-	-	ND	*	-	-	143	4	100	140
Dichloromethane	ND	ND	-	-	-		-	-	-	-	-	-
1,1,2,2-Tetrachloroethane	ND	ND	-	-	-	-	-	-	-	-	-	-
1,1-Dichloroethane	ND	ND	-	-	-	-	-	-	-	-	-	-
Additional Quality Assurance -- Diluted Samples												
Benzene	-	-	-	-	-	-	-	-	33800	19000	10000	150
Toluene	-	-	-	-	-	-	-	-	6160	2800	2000	170

ND - Not detected
*Unknown notation from Acurex

Table 27. GC/MS Verification Report
Quality Assurance Summary for Semivolatile Organics
Phase I Data

Raw Waste Influent

	Week 1				Week 2				Week 3			
	Concentration (µg/L)				Concentration (µg/L)				Concentration (µg/L)			
Compounds	Spiked	Mean Unspiked	Spike Level	Recovery %	Spiked	Mean Unspiked	Spike Level	Recovery %	Spiked	Mean Unspiked	Spike Level	Recovery %
Naphthalene	8000	3400	2000	230	600	1600	2000	-	3100	2800	2000	15
Isophorone	ND	ND	20	-	ND	ND	20	-	19	ND	20	95
2,4-Dinitrotoluene	ND	ND	20	-	ND	ND	20	-	ND	ND	20	
Acenaphthylene	340	220	200	60	310	180	200	65	410	250	200	80
Acenaphthene	100	25	20	380	37	12	20	130	38	16	20	110
Fluorene	80	28	20	260	39	27	20	60	81	62	20	95
Phenanthrene/anthracene	240	93	200	74	210	100	200	55	240	120	200	60
Chrysene/benzo(a)anthracene	38	22	20	80	52	40	20	60	46	26	20	100
Pyrene	22	12	20	50	24	16	20	40	24	13	20	55
Benzo(a)pyrene	27	17	20	50	41	29	20	60	38	20	20	90
Benzo(ghi)perylene	ND	*	20	-	20	12	20	40	66	7	20	300
Indeno(1,2,3-cd)pyrene	ND	*		-	22	12	20	50	16	4	20	160
Hexachlorobenzene	ND	ND	20	-	12	ND	20	60	16	ND	20	80
Phenol	2800	2700	5000	2	660	3600	5000	-	3200	6200	5000	-
4-Chloro-m-cresol	ND	ND	20	-	ND	ND	20	-	ND	ND	20	-
2,4-Dimethylphenol	1200	1000	1000	20	72	1100	1000	-	1300	2000	1000	-
Pentachlorophenol	20	ND	20	100	ND	ND	20	-	18	ND	20	90
2-Chlorophenol	ND	ND	20	-	ND	ND	20	-	7	ND	20	35
2,4-Dichlorophenol	8	ND	20	40	ND	ND	20	-	6	ND	20	30
2,4,6-Trichlorophenol	43	ND	20	210	ND	ND	20	-	30	ND	20	150

ND - Not detected
*Unknown notation from Acurex

Table 28. GC/MS Verification Report
Quality Assurance Summary for Volatile Organics
Phase I Data

Chlorination Effluent

	Week 1				Week 2				Week 3			
	Concentration (µg/L)				Concentration (µg/L)				Concentration (µg/L)			
Compounds	Spiked	Mean Unspiked	Spike Level	Recovery %	Spiked	Mean Unspiked	Spike Level	Recovery %	Spiked	Mean Unspiked	Spike Level	Recovery %
Chloroform	10500	9000	5500	27	13000	3700	5000	186	8000	8000	100	0
Benzene	5500	3200	3500	66	6700	2900	5000	76	2600	2600	100	0
Acrylonitrile	ND	3300			11000	970	5000	200	6400	2100	1000	430
Dichlorobromomethane	3200	1700	3000	50	4200	2600	2000	80	3100	3000	100	100
Dibromochloromethane	960	360	700	86	730	280	500	90	900	680	100	220
Carbon tetrachloride	84	16	50	97	66	46	100	20	170	50	100	120
1,2-Dichloroethane	70	26	70	63	130	*	100	120	90	16	100	74
trans-1,2-Dichloroethylene	8	ND	10	80	-	-	-	-	102	ND	100	100
Toluene	460	280	250	72	960	260	1000	70	350	250	100	100
Chlorobenzene	76	38	70	76	96	45	100	51	176	72	100	100
Bromoform	ND	ND	-	-	ND	ND	0	-	280	28	100	250
Ethylbenzene	-	-	-	-	-	-	-	-	90	ND	100	90
Dichloromethane	ND	24	-	-	-	-	-	-	-	-	-	-
1,1,2,2-Tetrachloroethane	ND	ND	10	-	-	-	-	-	-	-	-	-
1,1-Dichloroethane	ND	ND	10	-	-	-	-	-	-	-	-	-
Additional Quality Assurance -- Diluted Samples												
Chloroform	-	-	-	-	-	-	-	-	35500	22000	10000	140
Benzene	-	-	-	-	-	-	-	-	14400	5000	10000	94
Acrylonitrile	-	-	-	-	-	-	-	-	16000	1500	5000	290
Dichlorobromomethane	-	-	-	-	-	-	-	-	8000	2600	5000	110
Dibromochloromethane	-	-		-	-	-	-	-	2300	ND	2500	92
Toluene	-	-	-	-	-	-	-	-	2100	540	2500	62

ND - Not detected
*Unknown notation from Acurex

Table 29. GC/MS Verification Report
Quality Assurance Summary for Semivolatile Organics
Phase I Data

Chlorination Effluent

	Week 1				Week 2				Week 3			
	Concentration (µg/L)				Concentration (µg/L)				Concentration (µg/L)			
Compounds	Spiked	Mean Unspiked	Spike Level	Recovery %	Spiked	Mean Unspiked	Spike Level	Recovery %	Spiked	Mean Unspiked	Spike Level	Recovery %
Naphthalene	260	200	40	150	3	14	40	-	800	700	40	250
Isophorone	13	ND	20	65	ND	ND	20	-	4	ND	20	20
2,4-Dinitrotoluene	30	ND	20	150	ND	ND	20	-	ND	ND	20	
Acenaphthylene	22	*	20		7	4	20	15	36	14	20	110
Acenaphthene	150	110	20	200	16	5	20	55	40	6	20	170
Fluorene	120	80	20	200	31	10	20	105	51	23	20	140
Phenanthrene/anthracene	84	57	20	130	33	21	20	60	67	41	20	130
Chrysene/benzo(a)anthracene	25	*	20	-	43	18	20	125	30	8	20	110
Pyrene	11	*	20	-	17	4	20	65	19	2	20	85
Benzo(a)pyrene	14	*	20	-	24	11	20	65	15	6	20	45
Benzo(ghi)perylene	ND	ND	20	-	12	5	20	35	25	3	20	110
Indeno(1,2,3-cd)pyrene	ND	*	20	-	19	5	20	70	21	3	20	90
Hexachlorobenzene	43	ND	20	210	20	ND	20	100	22	ND	20	110
Phenol	*	*	20	-	ND	ND	20	-	ND	4	20	-
4-Chloro-m-cresol	ND	ND	20	-	ND	ND	20	-	ND	ND	-	-
2,4-Dimethylphenol	ND	ND	20	-	ND	ND	20	-	ND	ND	20	-
Pentachlorophenol	13	ND	20	65	30	*	20	150	27	ND	20	140
2-Chlorophenol	ND	10	20	-	ND	*	20	-	ND	ND	20	-
2,4-Dichlorophenol	270	180	200	45	41	*	200	20	170	14	200	78
2,4,6-Trichlorophenol	72	54	20	90	196	64	20	600	54	*	20	270

ND - Not detected
*Unknown notation from Acurex

Table 30. GC/MS Verification Report
Quality Assurance Summary for Volatile Organics
Phase I Data

Filtration Effluent

Compounds	Week 1				Week 2				Week 3			
	Concentration (µg/L)				Concentration (µg/L)				Concentration (µg/L)			
	Spiked	Mean Unspiked	Spike Level	Recovery %	Spiked	Mean Unspiked	Spike Level	Recovery %	Spiked	Mean Unspiked	Spike Level	Recovery %
Chloroform	16000	5200	2500	432	16000	15000	5000	20	8800	9400	100	-
Benzene	11300	3400	2100	379	5800	4000	5000	36	2700	2800	100	-
Acrylonitrile	1200	1200	-	-	5800	3400	2000	120	17400	11000	1000	640
Dichlorobromomethane	4100	1700	2100	114	4200	3000	2000	60	3100	3200	100	-
Dibromochloromethane	670	210	1000	46	720	360	500	72	910	770	100	140
Carbon tetrachloride	99	26	120	52	46	48	100	-	190	54	100	140
1,2-Dichloroethane	110	19	100	91	103	ND	100	100	120	20	100	100
trans-1,2-Dichloroethylene	ND	ND	10	-	-	-	-	-	120	ND	100	120
Toluene	570	380	200	95	450	240	500	42	326	260	100	66
Chlorobenzene	110	44	80	82	82	42	100	40	189	88	100	100
Bromoform	ND	ND	-	-	ND	ND	-	-	250	44	100	210
Ethylbenzene	-	-	-	-	-	-	-	-	105	ND	100	100
Dichloromethane	ND	24	-	-	-	-	-	-	-	-	-	-
1,1,2,2-Tetrachloroethane	ND	ND	10	-	-	-	-	-	-	-	-	-
1,1-Dichloroethane	ND	*	10	-	-	-	-	-	-	-	-	-
Additional Quality Assurance -- Diluted Samples												
Chloroform	-	-	-	-	-	-	-	-	44200	29000	10000	150
Benzene	-	-	-	-	-	-	-	-	15000	5300	10000	97
Acrylonitrile	-	-	-	-	-	-	-	-	41000	8500	5000	650
Dichlorobromomethane	-	-	-	-	-	-	-	-	8200	2800	5000	110
Dibromochloromethane	-	-	-	-	-	-	-	-	2100	260	2500	74
Toluene	-	-	-	-	-	-	-	-	2200	380	2500	73

ND - Not detected
*Unknown notation from Acurex

Table 31. GC/MS Verification Report
Quality Assurance Summary for Semivolatile Organics
Phase I Data

Filtration Effluent

Compounds	Week 1				Week 2				Week 3			
	Concentration (µg/L)				Concentration (µg/L)				Concentration (µg/L)			
	Spiked	Mean Unspiked	Spike Level	Recovery %	Spiked	Mean Unspiked	Spike Level	Recovery %	Spiked	Mean Unspiked	Spike Level	Recovery %
Naphthalene	230	140	200	45	530	160	200	180	1200	960	200	120
Isophorone	50	ND	20	250	36	ND	20	180	38	ND	20	190
2,4-Dinitrotoluene	ND	ND	20	-	ND	ND	20	-	ND	ND	20	-
Acenaphthylene	12	*	20	60	24	ND	20	120	25	4	20	100
Acenaphthene	90	230	20	-	32	6	20	130	37	12	20	120
Fluorene	80	250	20	-	34	5	20	140	40	12	20	140
Phenanthrene/anthracene	80	62	20	90	35	8	20	130	44	20	20	110
Chrysene/benzo(a)anthracene	*	*	20	-	6	4	20	10	27	4	20	120
Pyrene	*	ND	20	-	6	ND	20	30	21	ND	20	100
Benzo(a)pyrene	*	*	20	-	ND	3	20	-	9	1	20	40
Benzo(ghi)perylene	ND	ND	20	-	ND	2	20	-	15	ND	20	75
Indeno(1,2,3-cd)pyrene	*	ND	20	-	ND	2	20	-	18	ND	20	90
Hexachlorobenzene	15	ND	20	75	35	ND	20	170	20	ND	20	100
Phenol	600	380	20	1000	ND	ND	20	-	14	3	20	55
4-Chloro-m-cresol	ND	ND	20	-	ND	ND	20	-	14	*	-	-
2,4-Dimethylphenol	ND	ND	20	-	ND	ND	20	-	12	ND	20	60
Pentachlorophenol	6	ND	20	30	35	ND	20	170	120	ND	20	600
2-Chlorophenol	270	ND	20	1300	-	-	-	-	21	ND	20	100
2,4-Dichlorophenol	160	210	20	-	*	*	20	-	160	8	20	760
2,4,6-Trichlorophenol	91	84	20	35	116	60	20	280	220	25	20	480

ND - Not detected
*Unknown notation from Acurex

Table 32. GC/MS Verification Report
Quality Assurance Summary for Volatile Organics
Phase I Data

Carbon Activated Effluent

	Week 1				Week 2				Week 3			
	Concentration (μg/L)				Concentration (μg/L)				Concentration (μg/L)			
Compounds	Spiked	Mean Unspiked	Spike Level	Recovery %	Spiked	Mean Unspiked	Spike Level	Recovery %	Spiked	Mean Unspiked	Spike Level	Recovery %
Chloroform	*	ND	10	-	56	*	100	50	3300	2200	1000	110
Benzene	9	ND	10	90	130	27	100	103	130	ND	100	130
Acrylonitrile	59	52		-	5500	2500	100	3000	4700	3600	1000	110
Dichlorobromomethane	*	ND	10	-	ND	ND	-	-	132	57	100	75
Dibromochloromethane	ND	ND	10	-	ND	ND	-	-	66	ND	100	66
Carbon tetrachloride	*	ND	10	-	ND	ND	-	-	106	ND	100	106
1,2-Dichloroethane	*	ND	10	-	ND	ND	-	-	179	40	100	140
trans-1,2-Dichloroethylene	ND	ND	10	-	-	-	-	-	205	ND	100	200
Toluene	78	60	10	180	105	*	100	100	135	ND	100	140
Chlorobenzene	*	ND	10	-	ND	ND	-	-	112	ND	100	110
Bromoform	ND	ND	10	-	ND	ND	-	-	57	ND	100	57
Ethylbenzene	-	-	-	-	ND	ND	-	-	148	ND	100	150
Dichloromethane	ND	ND	10	-	-	-	-	-	-	-	-	-
1,1,2,2-Tetrachloroethane	*	ND	10	-	-	-	-	-	-	-	-	-
1,1-Dichloroethane	ND	ND	10	-	-	-	-	-	-	-	-	-

ND - Not detected
*Unknown notation from Acurex

Table 33. GC/MS Verification Report
Quality Assurance Summary for Semivolatile Organics
Phase I Data

Carbon Activated Effluent

	Week 1				Week 2				Week 3			
	Concentration (µg/L)				Concentration (µg/L)				Concentration (µg/L)			
Compounds	Spiked	Mean Unspiked	Spike Level	Recovery %	Spiked	Mean Unspiked	Spike Level	Recovery %	Spiked	Mean Unspiked	Spike Level	Recovery %
Naphthalene	1	ND	20	5	22	0.5	20	110	31	2	20	140
Isophorone	4	ND	20	20	37	ND	20	180	26	ND	20	130
2,4-Dinitrotoluene	2	ND	20	10	ND	ND	20	-	ND	ND	20	-
Acenaphthylene	2	ND	20	10	23	ND	20	120	27	ND	20	140
Acenaphthene	3	ND	20	15	23	ND	20	120	30	ND	20	150
Fluorene	2	ND	20	10	24	ND	20	120	27	ND	20	140
Phenanthrene/anthracene	3	ND	20	15	18	ND	20	90	25	ND	20	120
Chrysene/benzo(a)anthracene	4	ND	20	20	23	ND	20	120	22	ND	70	110
Pyrene	2	ND	20	10	17	ND	20	85	19	ND	70	95
Benzo(a)pyrene	3	ND	20	15	15	ND	20	75	12	ND	20	60
Benzo(ghi)perylene	3	ND	20	15	39	ND	20	190	13	ND	20	65
Indeno(1,2,3-cd)pyrene	3	ND	20	15	20	ND	20	100	11	ND	20	55
Hexachlorobenzene	2	ND	20	10	25	ND	20	120	20	ND	20	100
Phenol	5	ND	20	25	9	ND	20	45	*	ND	20	-
4-Chloro-m-cresol	ND	ND	20	-	ND	ND	20	-	ND	ND	20	-
2,4-Dimethylphenol	ND	ND	20	-	ND	ND	20	-	ND	ND	20	-
Pentachlorophenol	7	ND	20	35	27	ND	20	130	21	ND	20	100
2-Chlorophenol	ND	ND	20	-	4	ND	20	20	*	ND	20	-
2,4-Dichlorophenol	3	ND	20	15	22	ND	20	110	14	ND	20	70
2,4,6-Trichlorophenol	25	ND	20	125	48	ND	20	240	32	ND	20	160

ND - Not detected
*Unknown notation from Acurex

III. Quality Assurance Summary

B. Phase II Data

Table 34. GC/MS Verification Report
Quality Assurance Summary for Volatile Organics
Phase II Data

Raw Waste Influent

	Week 1				Week 2			
	Concentration (µg/L)				Concentration (µg/L)			
Compounds	Spiked	Mean Unspiked	Spike Level	Recovery %	Spiked	Mean Unspiked	Spike Level	Recovery %
Chloroform	96	7	100	89	105	22	100	83
Benzene	780	795	100	15	4200	4380	100	-
Acrylonitrile	2800	980	1000	182	2300	400	1000	190
Dichlorobromomethane	73	ND	100	73	76	16	100	60
Dibromochloromethane	70	ND	100	70	54	ND	100	54
Carbon tetrachloride	52	ND	100	52	89	ND	100	89
1,2-Dichloroethane	72	ND	100	72	81	ND	100	81
trans-1,2-Dichloroethylene	84	ND	100	84	94	ND	100	94
Toluene	320	270	100	50	1650	1545	100	105
Chlorobenzene	84	ND	100	84	102	ND	100	102
Bromoform	60	ND	100	60	22	ND	100	22
Ethylbenzene	82	6	100	76	117	8	100	109
	Additional Quality Assurance -- Diluted Samples							
Chloroform	10600	ND	10000	106	8100	ND	10000	81
Benzene	11400	1045	10000	104	22500	13700	10000	88
Acrylonitrile	7200	ND	5000	140	6700	ND	5000	134
Dichlorobromomethane	3800	ND	5000	76	3950	ND	5000	79
Dibromochloromethane	960	ND	2000	48	1100	ND	2500	44
Toluene	2600	458	2000	107	4000	2600	2500	56

ND - Not detected

Table 35. GC/MS Verification Report
Quality Assurance Summary for Semivolatile Organics
Phase II Data

Raw Waste Influent

Compounds	Week 1 Concentration (μg/L) Spiked	Week 1 Concentration (μg/L) Mean Unspiked	Week 1 Concentration (μg/L) Spike Level	Week 1 Recovery %	Week 2 Concentration (μg/L) Spiked	Week 2 Concentration (μg/L) Mean Unspiked	Week 2 Concentration (μg/L) Spike Level	Week 2 Recovery %
Naphthalene	2900	2250	5000	13	2100	1700	5000	8
Isophorone	40	ND	50	80	12	ND	50	24
2,4-Dinitrotoluene	ND	ND	50	-	ND	ND	50	-
Acenaphthylene	1400	225	2000	59	680	280	500	80
Acenaphthene	130	30	50	200	81	18	50	126
Fluorene	92	49	50	86	86	45	50	82
Phenanthrene/anthracene	310	275	50	70	250	150	50	200
Chrysene/benzo(a)anthracene	137	52	50	170	164	48	50	212
Pyrene	121	50	50	142	97	28	50	138
Benzo(a)pyrene	76	38	50	76	96	22	50	148
Benzo(ghi)perylene	110	28	50	164	175	5	50	340
Indeno(1,2,3-cd)pyrene	94	28	50	132	150	8	50	280
Hexachlorobenzene	43	ND	-	-	-	-	-	-
Phenol	3400	3705	5000	-	9400	4950	5000	89
2,4-Dimethylphenol	2480	1990	2000	25	5590	2650	2000	147
Pentachlorophenol	101	ND	50	202	180	ND	50	360
2-Chlorophenol	64	ND	100	64	35	ND	100	35
2,4-Dichlorophenol	58	ND	50	116	67	ND	50	134
2,4,6-Trichlorophenol	150	ND	100	150	170	ND	100	170

ND - Not detected

Table 36 . GC/MS Verification Report
Quality Assurance Summary for Volatile Organics
Phase II Data

Chlorination Effluent

	Week 1				Week 2			
	Concentration (µg/L)				Concentration (µg/L)			
Compounds	Spiked	Mean Unspiked	Spike Level	Recovery %	Spiked	Mean Unspiked	Spike Level	Recovery %
Chloroform	5800	6100	100	300	14700	13000	100	170
Benzene	210	140	100	70	4660	4450	100	210
Acrylonitrile	1300	415	1000	89	1514	600	1000	91
Dichlorobromomethane	930	915	100	15	3120	3470	100	-
Dibromochloromethane	860	730	100	130	1210	1050	100	160
Carbon tetrachloride	100	ND	100	100	414	290	100	124
1,2-Dichloroethane	93	11	100	82	100	28	100	72
trans-1,2-Dichloroethylene	85	ND	100	85	105	ND	100	105
Toluene	105	13	100	92	680	565	100	115
Chlorobenzene	300	205	100	95	155	48	100	107
Bromoform	970	685	100	285	230	26	100	204
Ethylbenzene	100	ND	100	100	104	ND	100	104
Additional Quality Assurance -- Diluted Samples								
Chloroform	23000	11000	10000	120	50300	42500	10000	78
Benzene	10400	395	10000	100	16300	7050	10000	92
Acrylonitrile	3400	505	5000	58	2690	530	5000	43
Dichlorobromomethane	4900	445	5000	89	7800	2600	5000	104
Dibromochloromethane	1500	ND	2500	60	2200	ND	2500	88
Toluene	2300	ND	2500	92	2250	560	2500	68

ND - Not detected

Table 37. GC/MS Verification Report
Quality Assurance Summary for Semivolatile Organics
Phase II Data

Chlorination Effluent

	Week 1				Week 2			
	Concentration (µg/L)				Concentration (µg/L)			
Compounds	Spiked	Mean Unspiked	Spike Level	Recovery %	Spiked	Mean Unspiked	Spike Level	Recovery %
Naphthalene	130	23	50	214	215	220	50	-
Isophorone	ND	ND	50	0	26	ND	50	52
2,4-Dinitrotoluene	ND	ND	50	0	27	ND	50	54
Acenaphthylene	74	6	50	138	64	14	50	100
Acenaphthene	110	17	50	186	66	48	50	36
Fluorene	85	2	50	170	91	42	50	98
Phenanthrene/anthracene	85	15	50	140	120	80	50	80
Chrysene/benzo(a)anthracene	79	7	50	158	125	54	50	142
Pyrene	58	3	50	116	53	10	50	86
Benzo(a)pyrene	27	4	50	54	53	8	50	94
Benzo(ghi)perylene	66	ND	50	132	140	13	50	270
Indeno(1,2,3-cd)pyrene	62	2	50	124	129	22	50	200
Hexachlorobenzene	32	ND	50	64	36	ND	50	72
Phenol	27	51	50	-	19	4	50	30
2,4-Dimethylphenol	40	13	50	54	31	ND	50	62
Pentachlorophenol	128	ND	50	256	220	ND	50	400
2-Chlorophenol	64	23	100	41	59	11	100	48
2,4-Dichlorophenol	770	ND	500	154	750	46	500	140
2,4,6-Trichlorophenol	480	ND	400	120	590	64	400	130

ND - Not detected

Table 38. GC/MS Verification Report
Quality Assurance Summary for Volatile Organics
Phase II Data

Chemical Dechlorination Effluent

Compounds	Week 1				Week 2			
	Concentration (µg/L)				Concentration (µg/L)			
	Spiked	Mean Unspiked	Spike Level	Recovery %	Spiked	Mean Unspiked	Spike Level	Recovery %
Chloroform	4600	4650	100	–	13300	8500	100	680
Benzene	190	93	100	97	5105	4500	100	600
Acrylonitrile	1700	235	1000	147	1460	470	1000	99
Dichlorobromomethane	890	785	100	105	3420	2770	100	65
Dibromochloromethane	810	590	100	220	1090	795	100	295
Carbon tetrachloride	130	ND	100	130	480	200	100	280
1,2-Dichloroethane	120	10	100	110	120	9	100	111
trans-1,2-Dichloroethylene	94	ND	100	94	97	ND	100	97
Toluene	110	7	100	103	620	508	100	112
Chlorobenzene	260	130	100	130	160	42	100	118
Bromoform	770	410	100	360	238	31	100	207
Ethylbenzene	100	ND	100	100	100	ND	100	110
Additional Quality Assurance -- Diluted Samples								
Chloroform	18000	7000	10000	110	45900	37900	10000	80
Benzene	10000	115	10000	99	15500	5710	10000	98
Acrylonitrile	5900	ND	5000	118	4680	ND	5000	93
Dichlorobromomethane	5900	375	5000	110	7210	1770	5000	109
Dibromochloromethane	2300	ND	2500	92	2130	ND	2500	85
Toluene	1800	ND	2500	72	2520	265	2500	90

ND - Not detected

Table 39 GC/MS Verification Report
Quality Assurance Summary for Semivolatile Organics
Phase II Data

Chemical Dechlorination Effluent

	Week 1				Week 2			
	Concentration (µg/L)				Concentration (µg/L)			
Compounds	Spiked	Mean Unspiked	Spike Level	Recovery %	Spiked	Mean Unspiked	Spike Level	Recovery %
Naphthalene	177	88	50	178	162	340	50	
Isophorone	ND	ND	50	-	16	ND	50	32
2,4-Dinitrotoluene	ND	ND	50	-	16	ND	50	32
Acenaphthylene	60	6	50	108	15	48	50	-
Acenaphthene	71	7	50	128	46	56	50	-
Fluorene	53	7	50	92	42	71	50	-
Phenanthrene/anthracene	77	33	50	88	90	121	50	-
Chrysene/benzo(a)anthracene	108	25	50	166	43	85	50	-
Pyrene	-	-	-	-	-	-	-	-
Benzo(a)pyrene	37	2	50	70	5	15	50	-
Benzo(ghi)perylene	15	2	50	26	ND	10	50	-
Indeno(1,2,3-cd)pyrene	32	2	50	60	8	14	50	-
Hexachlorobenzene	36	ND	50	72	-	-	-	-
Phenol	28	7	50	42	48	18	50	60
2,4-Dimethylphenol	29	ND	50	58	460	8	600	75
Pentachlorophenol	128	ND	50	256	65	ND	50	130
2-Chlorophenol	59	10	100	49	81	22	100	59
2,4-Dichlorophenol	710	2	500	141	580	54	500	105
2,4,6-Trichlorophenol	450	ND	400	112	350	61	400	72

ND - Not detected

Table 40. GC/MS Verification Report
Quality Assurance Summary for Volatile Organics
Phase II Data

Filtration Effluent

	Week 1				Week 2			
	Concentration (μg/L)				Concentration (μg/L)			
Compounds	Spiked	Mean Unspiked	Spike Level	Recovery %	Spiked	Mean Unspiked	Spike Level	Recovery %
Chloroform	5000	4650	100	350	14900	12400	100	2500
Benzene	220	115	100	105	5590	5720	100	-
Acrylonitrile	1600	215	1000	139	1820	520	1000	130
Dichlorobromomethane	1000	885	100	115	3520	3600	100	-
Dibromochloromethane	1150	935	100	215	1180	1030	100	150
Carbon tetrachloride	120	ND	100	120	426	300	100	126
1,2-Dichloroethane	120	13	100	107	120	23	100	97
trans-1,2-Dichloroethylene	95	ND	100	95	89	ND	100	89
Toluene	115	10	100	105	589	510	100	79
Chlorobenzene	274	170	100	104	149	42	100	107
Bromoform	970	650	100	320	330	36	100	300
Ethylbenzene	96	ND	100	96	101	ND	100	101
Additional Quality Assurance -- Diluted Samples								
Chloroform	21000	7050	10000	140	37500	30000	10000	75
Benzene	11000	125	10000	109	28600	6020	10000	165
Acrylonitrile	6500	ND	5000	130	2400	285	5000	42
Dichlorobromomethane	6600	415	5000	124	10600	1970	5000	170
Dibromochloromethane	2800	ND	2500	112	2490	ND	2500	100
Toluene	2000	ND	2500	80	3100	ND	2500	124

ND - Not detected

Table 41. GC/MS Verification Report
Quality Assurance Summary for Semivolatile Organics
Phase II Data

Filtration Effluent

Compounds	Week 1 Concentration (µg/L) Spiked	Week 1 Concentration (µg/L) Mean Unspiked	Week 1 Concentration (µg/L) Spike Level	Week 1 Recovery %	Week 2 Concentration (µg/L) Spiked	Week 2 Concentration (µg/L) Mean Unspiked	Week 2 Concentration (µg/L) Spike Level	Week 2 Recovery %
Naphthalene	156	126	50	60	328	274	50	108
Isophorone	ND	ND	50	-	ND	ND	50	-
2,4-Dinitrotoluene	ND	ND	50	-	ND	ND	50	-
Acenaphthylene	42	2	50	80	41	2	50	78
Acenaphthene	55	9	50	92	39	ND	50	78
Fluorene	54	2	50	104	55	6	50	98
Phenanthrene/anthracene	51	4	50	94	65	8	50	114
Chrysene/benzo(a)anthracene	77	ND	50	154	110	ND	50	205
Pyrene	48	ND	50	96	86	ND	50	172
Benzo(a)pyrene	28	ND	50	56	52	ND	50	104
Benzo(ghi)perylene	25	ND	50	50	ND	ND	50	-
Indeno(1,2,3-cd)pyrene	29	ND	50	58	25	ND	50	50
Hexachlorobenzene	35	ND	-	-	67	ND	50	134
Phenol	470	410	50	120	27	18	50	18
2,4-Dimethylphenol	ND	ND	50	-	34	6	50	56
Pentachlorophenol	148	ND	50	300	55	ND	50	110
2-Chlorophenol	80	20	100	60	58	22	100	72
2,4-Dichlorophenol	190	4	500	137	440	59	500	76
2,4,6-Trichlorophenol	507	ND	400	127	300	73	400	57

ND - Not detected

APPENDIX B-4. ALKALINE CHLORINATION PILOT STUDY DATA

Run No.	Date	SS	Phenol	NH_3	S	CN_T	CN_A	SCN	TKN	TDS	Cl^-	Color	O&G	NO_2	BOD	TOC	pH
No. 1																	
Raw	11/29-30	263	98	717	26	100.0	80.2	245	815	6,780	1,525	280	-	-	-	400	8.7
CN Tank	11/29-30	305	-	106	-	19.0	<0.05	27	-	26,600	-	300/400	-	-	-	-	-
Alk. Chlor. Eff.	11/29-30	110	0.4	2	<0.2	11.6	9.0	3.0	130	26,700	9,200	200/300	-	-	-	370	6.8
No. 2																	
Raw	12/2-3	69	80	224	27	130.0	123.5	320	-	4,120	-	-	-	-	-	330	8.1
CN Tank	12/2-3	67	-	11	<0.2	5.0	4.0	<1	-	-	-	-	-	-	-	205	-
Alk. Chlor. Eff.	12/2-3	15	0.30	4	<0.2	9.4	6.4	<1	-	19,500	-	-	-	-	-	135	6.5
No. 3																	
Raw	12/3-4	48	96	241	19	125.9	124.3	205	-	-	-	-	3	-	-	425	8.8
CN Tank	12/3-4	-	-	34	-	.4	<.05	2.5	-	-	-	-	-	-	-	185	-
Alk. Chlor. Eff.	12/3-4	28	0.11	1	<0.2	.2	<.05	<1	-	-	-	-	3	-	-	120	5.9
No. 4																	
Raw	12/4-5	40	110	370	20	100.7	98.6	200	450	2,930	1,125	160/200	-	-	-	230	8.2
CN Tank	12/4-5	63	-	34	-	3.4	2.4	<1	-	16,900	-	60	-	-	-	90	-
Alk. Chlor. Eff.	12/4-5	34	0.20	1	<0.2	.3	<.05	<1	50	22,200	-	120	-	-	-	125	6.3
No. 5																	
Raw	12/5-6	35	124	142	14	83.8	76.7	155	-	-	-	-	-	-	-	336	8.6
CN Tank	12/5-6	-	-	65	1.5	9.4	1.9	1.5	-	-	-	-	-	-	-	-	-
Alk. Chlor. Eff.	12/5-6	19	1.5	2	6.8	3.6	<.05	<1	-	-	-	-	-	-	-	228	6.1
No. 6																	
Raw	12/6-7	152	70	260	26	70.7	57.1	260	344	3,235	1,375	300	6	1.3	525	415	8.7
CN Tank	12/6-7	108	-	95	-	.2	<.05	<1	-	16,950	-	50	-	-	-	-	-
Alk. Chlor. Eff.	12/6-7	102	0.40	3	<.2	3.8	<.05	<1	84	16,650	7,250	100	15	5.0	140	270	6.5
No. 7																	
Raw	12/7-8	57	167	-	64.0	56.5	-	-	-	-	-	-	-	-	-	-	8.6
Alk. Chlor. Eff.	12/7-8	48	3	-	1.0	1.0	-	-	-	-	-	-	-	-	-	-	6.3
No. 8																	
Raw	12/8-9	58	174	-	69.5	65.6	-	-	-	-	-	-	-	-	-	-	8.7
Alk. Chlor. Eff.	12/8-9	34	3	-	4.0	1.5	-	-	-	-	-	-	-	-	-	-	6.7

continued

APPENDIX B-4. (continued)

Run No.	Date	SS	Phenol	NH_3	S	CN_T	CN_A	SCN	TKN	TDS	Cl^-	Color	O&G	NO_2	BOD	TOC	pH
No. 9																	
Raw	12/9-10	55	760	126	26.9	145.0	117.2	300	169	4,190	1,620	400	3	-	-	368	10.0
CN Tank	12/9-10	27	-	34	-	3.2	<.05	14	-	16,700	7,190	50	-	-	-	196	-
Alk. Chlor. Eff.	12/9-10	14	0.60	2	<.2	3.8	0.8	14	40	17,300	200	-	3	-	-	192	6.7
No. 10																	
Raw	12/11-11	65	68.0	106	24.8	267.5	261.4	300	-	-	-	-	-	-	-	376	9.6
Alk. Chlor Eff.	12/11-11	49	0.35	2	<.2	I	I	45	-	-	-	-	-	-	-	272	6.0
No. 11																	
Raw	12/11-12	97	-	101	24.6	99.6	66.7	290	167	4,580	1,620	300	-	3.7	-	304	10.8
CN Tank	12/11-12	48	80.0	8	-	I	I	7.5	-	21,500	-	75	-	5.0	-	-	-
Alk. Chlor. Eff.	12/11-12	35	<.01	2	<.2	I	I	9.5	-	21,200	8,750	200	-	8.4	-	192	6.4
No. 12																	
Raw	12/12-13	52	80.0	214	25.9	97.7	93.3	290	-	-	-	-	-	-	-	352	9.5
CN Tank	12/12-13	-	-	34	-	4.6	<.05	125	-	-	-	-	-	-	-	-	-
Alk. Chlor. Eff.	12/12-13	24	0.55	3	<0.2	3.7	0.5	7.8	-	-	-	-	-	-	-	232	6.3
No. 13																	
Raw	12/13-14	48	850.0	320	24.8	79.7	62.7	300	335	4,070	1,560	300	10	2.0	450	348	8.8
CN Tank	12/13-14	31	-	78	-	.5	<.05	8.5	-	27,000	-	50	-	-	-	-	-
Alk. Chlor. Eff.	12/13-14	11	0.50	4	<.2	7.9	<.05	15	37	19,900	-	-	15	6.7	24	-	6.6
No. 14																	
Raw	12/15	-	-	637	-	58.0	29.0	-	-	-	-	-	-	-	-	-	8.8
Alk. Chlor. Eff.	12/15	-	-	270	-	8.7	<.05	-	-	-	-	-	-	-	-	-	6.2
No. 15																	
Raw	12/15	-	-	467	-	63.0	19.5	-	-	-	-	-	-	-	-	-	8.8
Alk. Chlor Eff.	12/15	-	-	4.5	-	8.2	5.4	-	-	-	-	-	-	-	-	-	6.2
No. 16																	
Raw	12/15	-	-	347	-	47.3	39.6	-	-	-	-	-	-	-	-	-	8.8
Alk. Chlor. Eff.	12/15	-	-	3	-	10.5	0.45	-	-	-	-	-	-	-	-	-	6.3
No. 17																	
Raw	12/15	-	-	355	-	56.6	30.8	-	-	-	-	-	-	-	-	-	8.9
Alk. Chlor. Eff.	12/15	-	-	2	-	10.3	<.05	-	-	-	-	-	-	-	-	-	6.2

I: Denotes Interference.

continued

APPENDIX B-4. (continued)

Run No.	Date	SS	Phenol	NH_3	S	CN_T	CN_A	SCN	TKN	TDS	Cl^-	Color	O&G	NO_2	BOD	TOC	pH
No. 18																	
Raw	12/16	-	-	216	-	75.0	0.5	-	-	-	-	-	-	-	-	-	9.1
Alk. Chlor. Eff.	12/16	-	-	4	-	5.8	<.05	-	-	-	-	-	-	-	-	-	6.2
No. 19																	
Raw	12/16-17	171	80	202	27.3	83.8	82.4	320	-	-	-	-	-	-	-	630	9.1
CN Tank	12/16-17	-	-	56	-	11.9	10.0	60	-	-	-	-	-	-	-	-	-
Alk. Chlor. Eff.	12/16-17	129	1.0	2	<0.2	13.0	12.8	3	-	-	-	-	-	-	-	402	6.2
No. 20																	
Raw	12/17-18	123	80	193	25.7	83.0	71.3	295	260	4,150	1,500	400/600	11	2.5	-	546	9.3
CN Tank	12/17-18	77	-	71	-	6.4	1.3	45	-	19,000	-	600/800	-	-	-	-	-
Alk. Chlor. Eff.	12/17-18	139	1.4	3	<.2	12.9	3.5	45	36	17,700	-	300/400	8	4.8	-	420	6.9
No. 21																	
Raw	12/18-19	104	69	269	27.3	131.3	112.2	275	-	-	-	-	-	-	-	445	8.8
CN Tank	12/18-19	-	-	34	-	5.3	0.4	17	-	-	-	-	-	-	-	-	-
Alk. Chlor. Eff.	12/18-19	71	1.4	3	<.2	6.8	0.6	8	-	-	-	-	-	-	-	345	6.4
No. 22																	
Raw	12/19-20	64	78	235	24.4	105.0	92.1	275	-	-	-	300/400	-	-	-	444	8.7
CN Tank	12/19-20	52	-	54	-	11.4	0.8	20	-	-	-	100/200	-	-	-	-	-
Alk. Chlor. Eff.	12/19-20	71	3.0	2	<.2	8.9	<.05	23	-	-	-	100/200	-	-	-	270	6.4
No. 23																	
Raw	1/3/80	-	-	140	-	-	-	-	-	-	-	-	-	-	-	-	8.5
Alk. Chlor. Eff.	1/3/80	-	-	64	-	-	-	-	-	-	-	-	-	-	-	-	7.1
No. 24																	
Raw	1/4/80	-	-	409	-	-	-	-	-	-	-	-	-	-	-	-	8.4
Alk. Chlor. Eff.	1/4/80	-	-	185	-	-	-	-	-	-	-	-	-	-	-	-	-
No. 25																	
Raw	1/4/80	-	-	700	-	-	-	-	-	-	-	-	-	-	-	-	6.2
Alk. Chlor. Eff.	1/4/80	-	-	5	-	-	-	-	-	-	-	-	-	-	-	-	7.2
No. 26																	
Raw	1/6/80	-	-	358	-	-	-	-	-	-	-	-	-	-	-	-	8.4
Alk. Chlor. Eff.	1/6/80	-	-	<1	-	-	-	-	-	-	-	-	-	-	-	-	7.1

continued

APPENDIX B-4. (continued)

Run No.	Date	SS	Phenol	NH_3	S	CN_T	CN_A	SCN	TKN	TDS	Cl^-	Color	O&G	NO_2	BOD	TOC	pH
No. 27																	
Raw	1/6/80	-	-	442	-	-	-	-	-	-	-	-	-	-	-	-	8.8
Alk. Chlor. Eff.	1/6/80	-	-	<1	-	-	-	-	-	-	-	-	-	-	-	-	7.05
No. 28																	
Raw	1/6/80	-	-	610	-	-	-	-	-	-	-	-	-	-	-	-	8.4
Alk. Cnlor. Eff.	1/6/80	-	-	<1	-	-	-	-	-	-	-	-	-	-	-	-	-
No. 29																	
Raw	1/6/80	-	-	622	-	-	-	-	-	-	-	-	-	-	-	-	8.0
Alk. Chlor. Eff.	1/6/80	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	6.4
No. 30																	
Raw	1/7/80	67	-	800	-	64.0	50.5	240	-	-	-	-	-	-	-	-	7.4
Dechlor. Tank	1/7/80	23	-	-	-	-	-	-	-	-	-	200/300	-	-	-	-	-
DMF Eff.	1/7/80	6	-	<1	-	0.8	<.05	3.5	-	-	-	-	-	-	-	-	7.5
No. 31																	
Raw	1/9/80	116	130	1925	26	44.4	11.8	255	-	-	-	100/150	138	2.0	-	618	3.8
Alk. Chlor. Eff.	1/9/80	42	0.6	<1	<.2	I	I	45	-	-	-	50/75	71	14.4	-	696	6.5
Dechlor. Tank	1/9/80	80	-	-	-	-	-	-	-	-	-	-	-	-	-	-	6.6
DMF Eff.	1/9/80	3	0.05	26	<.2	I	I	45	-	-	-	80/100	43	9.9	-	516	-
No. 32																	
Raw	1/9/80	116	130	1925	26	44.4	11.8	255	-	-	-	100/150	138	-	-	618	3.8
Alk. Chlor. Eff.	1/9/80	58	0.4	44	<.2	I	I	55	-	-	-	60/80	-	-	-	-	7.2
Dechlor.	1/9/80	84	-	-	-	I	I	-	-	-	-	60/80	-	-	-	-	6.3
DMF Eff.	1/9/80	1	<.05	<1	<.2	I	I	0.2	-	-	-	80/100	-	-	-	-	-
CN Tank	1/9/80	50	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
No. 33																	
Raw	1/9/80	247	-	2150	-	40.5	1.6	250	-	-	-	-	-	-	-	-	4.1
Alk. Chlor. Eff.	1/9/80	119	-	41	-	I	I	220	-	-	-	-	-	-	-	-	7.0
Dechlor.	1/9/80	124	-	-	-	-	-	-	-	-	-	-	-	-	-	-	6.4
DMF Eff.	1/9/80	4	-	-	-	4.9	3.7	8	-	-	-	-	-	-	-	-	-
No. 34																	
Raw	1/10/80	187	280	2130	260	4.7	2.4	2	2190	-	-	300/400	147	-	-	-	8.0
Alk. Chl r. Eff.	1/10/80	53	0.05	19	<.2	I	I	13.5	38	-	-	20/30	12	-	-	-	6.4
Dechlor.	1/10/80	70	-	-	-	-	-	-	-	-	-	-	-	-	-	-	5.8
DMF Eff.	1/10/80	9	<.05	<1	<.2	I	I	2.5	56	-	-	80/100	14	-	-	-	-

continued

I: Denotes Interference

APPENDIX B-4. (continued)

Run No.	Date	SS	Phenol	NH_3	S	CN_T	CN_A	SCN	TKN	TDS	Cl^-	Color	O&G	NO_3	BOD	TOC	pH
No. 35																	
Raw	1/11/80	361	38	800	11.6	14.1	13.9	185	-	5,960	-	100/150	139	-	-	515	6.8
Dechlor. Tank	1/11/80	145	-	-	-	-	-	<1	-	-	-	-	57	-	-	-	6.2
DMF Eff.	1/11/80	2	0.3	<1	<.2	I	I	<1	-	24,200	-	75/100	11	-	-	140	7.1
No. 36																	
Raw	1/13/80	66	154	390	-	88.2	81.5	260	-	-	-	150/200	-	-	-	465	9.3
Dechlor. Tank	1/13/80	39	-	-	-	-	-	-	-	-	-	300/400	-	-	-	-	7.2
DMF Eff.	1/13/80	6	1.4	2	-	9.4	<.05	3.1	-	-	-	200/250	-	-	-	-	-
No. 37																	
Raw	1/15/80	52	156	203	154	99.2	93.2	215	-	-	-	150/200	-	-	-	380	9.0
Dechlor. Tank	1/15/80	53	-	-	-	-	-	-	-	-	-	-	-	-	-	-	6.6
DMF Eff.	1/15/80	7	0.6	1	6.6	9.4	3.4	3.0	-	-	-	200/250	-	-	-	-	7.7
No. 38																	
Raw	1/16/80	71	120	204	106	127.5	121.5	315	-	-	-	500/600	53	-	-	-	9.6
Dechlor. Tank	1/16/80	40	-	-	-	-	-	-	-	-	-	150/200	-	-	-	-	7.0
DMF Eff.	1/16/80	<1	1.0	4	36.1	10.3	4.9	3.4	-	-	-	200/250	2	-	-	-	7.5
No. 39																	
Raw	1/16-17/80	60	170	184	87.8	85.0	84.9	460	-	-	-	300/400	40	-	-	550	9.9
Alk. Chlor. Eff.	1/16-17/80	28	0.8	111	47.2	3.4	<.05	14	-	-	-	40/60	17	-	-	750	7.0
Dechlor. Tank	1/16-17/80	37	-	-	-	-	-	-	-	-	-	-	-	-	-	-	7.3
DMF Eff.	1/16-17/80	1	0.6	1	99.8	4.7	2.6	5.0	-	-	-	200/250	2	-	-	590	7.65
No. 40																	
Raw	1/17/80	26	130	161	38.7	87.4	84.0	370	-	-	-	600/700	40	3.1	-	445	10.0
Dechlor. Tank	1/17/80	10	-	-	-	-	-	-	-	-	-	50/75	17	-	-	-	-
DMF Eff.	1/17/80	1	-	<1	<.2	I	I	4.0	-	-	-	300/350	2	46	-	750	6.4

I: Denotes Interference.

APPENDIX B-5. COMPARISON OF FIELD VERSUS LABORATORY AMMONIA VALUES - ALKALINE CHLORINATION EFFLUENT

Run no.	Field ammonia value, mg/l	Laboratory ammonia value, mg/l
1	2	90
2	4	30
3	1	17
4	1	84
5	2	22
6	3	8
7	3	20
8	3	20
9	2	17
10	2	8
11	2	8
12	3	3
13	4	7
14	270	286
15	4.5	88
16	3	8
17	2	17
18	4	20
19	2	6
20	3	7
21	3	7
22	2	9
23	64	133
24	185	218
25	5	72
26	<1	26
27	<1	19
28	<1	24
29	1	18
30	<1	49
31	<1	26
32	<1	37
33	-	43
34	<1	35
35	<1	19
36	2	34
37	1	22
38	4	16
39	1	15
40	<1	2

APPENDIX B-6. ALKALINE CHLORINATION CHEMICAL USAGE INFORMATION

Run No.	Flow lpm	Rate gpm	pH in	ORP mv	25% NaOH usage ℓ/1,000 ℓ (gal./1,000 gal.)	66° Be' H_2SO_4 usage ℓ/1,000 ℓ (gal./1,000 gal.)	15% NaOCl usage ℓ/1,000 ℓ (gal./1,000 gal.)	Effluent chlorine residual mg/l	Wastewater temperature °C
1	7.57	2.0	6.4	850	5.77	0.94	38.5	81.5	32.0
2	7.57	2.0	8.1	800	3.14	0.57	43.9	131	32.0
3	7.57	2.0	8.7	840	3.36	0.71	36.3	74	27.0
4	7.57	2.0	7.5	840	3.90	0.84	48.1	124	30.0
5	7.57	2.0	8.6	700	-	-	48.1	-	31.0
6	7.95	2.1	8.3	700	3.47	0.50	35.0	85	31.0
7	7.57	2.0	8.2	750	3.21	0.53	36.5	111	34.0
8	8.33	2.2	8.7	900	2.67	0.55	34.8	105	-
9	7.57	2.0	9.5	700	2.6	0.58	40.0	69	-
10	11.36	3.0	9.5	900	2.5	0.85	39.8	46	-
11	9.46	2.5	10.6	960	2.4	0.90	43.6	80	-
12	7.19	1.9	8.8	960	3.95	0.97	40.8	87	29.5
13	8.33	2.2	8.5	950	1.84	0.80	45.5	130	32.5
14	8.33	2.2	8.8	500	11.7	2.82	64.9	280	29.0
15	8.33	2.2	8.8	600	5.0	-	50.5	71	30.0
16	8.33	2.2	8.8	700	5.2	-	36.7	57	32.0
17	8.33	2.2	8.9	800	4.1	-	43.4	57	34.0
18	8.33	2.2	9.1	1,000+	5.5	-	41.3	287	33.0
19	8.33	2.2	9.1	920	2.0	-	31.8	65	32.0
20	7.57	2.0	9.2	940	3.5	0.88	17.0	73	28.5
21	7.57	2.0	8.9	940	5.7	1.11	45.7	70	29.5
22	7.57	2.0	8.5	940	-	-	23.8	85	31.0
23	7.57	2.0	8.5	500	0.35	0.69	14.7	118	-
24	7.57	2.0	7.3	600	7.8	0.99	30.3	517	37.0
25	7.57	2.0	5.8	700	8.1	0.46	56.5	80	37.0
26	7.57	2.0	8.4	820	5.9	1.45	32.6	47	-
27	7.57	2.0	8.8	900	5.3	1.38	43.5	83	-
28	6.43	1.7	8.4	950	7.6	2.0	58.8	195	-
29	7.57	2.0	8.0	990	5.1	1.1	56.8	397	-
30	7.57	2.0	-	900	8.0	1.05	71.4	-	-
31	7.57	2.0	3.5	780	23.8	4.8	95.2	146	32.0
32	7.57	2.0	3.0	800	19	4.0	95.2	191	31.5
33	7.57	2.0	3.3	800	21	2.8	119.4	177	31.0
34	4.92	1.3	8.0	800	15.9	1.9	127.3	7,160	-
35	7.57	2.0	7.9	820	2.5	0.64	58.8	114	36.0
36	6.62	1.75	8.5	800	2.5	1.26	51.4	85	35.0
37	7.57	2.0	8.2	850	3.5	1.1	42.3	138	35.0
38	7.57	2.0	8.7	850	9.0	1.3	47.6	1,380	-
39	8.71	2.3	8.2	900	3.0	1.4	55.0	199	-
40	7.57	2.0	8.2	1,000+	-	6.0	148.2	4,950	-

APPENDIX B-7. DUAL MEDIA FILTRATION RESULTS - ALKALINE CHLORINATION EFFLUENT (NO POLYMER)

Filtration Rate		Run No.	Date	Headloss		Run Time Hrs	Suspended Solids, mg/l		Percent Solids Removal	Solids Loading	
l/min/m²	gpm/ft²			Meters	Feet		Inf.	Eff.		kg SS/m²/m m.L.	lb SS/ft²/ft m.L.
77.7	1.9	1	11/29-11/30	0.5	1.7	16.7	110	13	88	14.6	.91
73.6	1.8	2	12/1-12/2	0.2	0.7	31.5	15	11	27	2.1	.13
73.6	1.8	3	12/3-12/6	0.3	1.0		28	16	43		
			12/4-12/5	0.3	1.0		34	8	76		
			12/5-12/6	0.3	1.0	65	19	10	47	15.1	.936
73.6	1.8	4	12/6-12/7	0.8	2.7	19.3	102	14	86	9.1	.566
			12/7-12/8	1.1	3.7	46.3				15.9	.99
69.5	1.7		12/8-12/9	0.2	0.7	21.5	34	2	94	13.4	.835
69.	1.7	6	12/9-12/10	0.2	0.8	30.0	14	4	71	5.3	.33
65.4	1.6	7	12/11-12/11	-			49	8	84		
			12/11-12/12	0.3			35	8	77		
			12/12-12/13	-	0.9	23.5	24	9	63	6.2	.39
69.5	1.7	8	12/13-12/14	0.2	0.5	18.8	11	4	64	3.5	.22
73.6	1.8	9	12/16-12/17	-			129	36	72		
			12/17-12/18	0.3	1.0	42.5	139	18	87	66	4.1
			12/18-12/19	-			71	8	89		
			12/19-12/20	-			7	10	-		

APPENDIX B-8. DUAL MEDIA FILTRATION RESULTS - ALKALINE CHLORINATED EFFLUENT (WITH POLYMER)

Filtration Rate		Run		Headloss		Run Time	Suspended Solids, mg/l		Percent Solids	Solids Loading	
l/min/m²	gpm/ft²	No.	Date	Meters	Feet	Hr.	Inf.	Eff.	Removal	kg SS/m²/m H.L.	lb SS/ft²/ft H.L.
65.5	1.7	1A	1/6-1/7	0.2	0.7	17.5	23	6	74	5.8	.36
73.6	1.8	4A	1/8-1/9	0.2	0.6	-	80	3	96	-	-
		5A	1/9	-	-	-	84	1	99	-	-
		6A	1/9	-	-	-	124	4	97	-	-
40.5	1.0	7A	1/10	0.2	0.5	7.0	70	9	87	6.9	.43
60.7	1.5	8A	1/10-1/11	-	-	-	145	2	99	-	-
		9A	1/12-1/13	-	-	-	152	1	99	-	-
		10A	1/13-1/14	-	-	43.5	39	-	-	-	-
57.3	1.4	11A	1/14-1/15	-	-	18	53	7	87	-	-
		12A	1/15-1/16	-	-	36	40	1	97	-	-
57.3	1.4	13A	1/16-1/17	-	-	29.5	37	1	97	-	-
		14A	1/17-1/18	-	-	-	10	1	90	-	-
204.6	5.0	1B	1/17-1/18	0.5	1.7	7	6	6	-	(UNTREATED COKE PLANT WASTEWATER)	

APPENDIX B-9. ACTIVATED CARBON DECHLORINATION DATA SUMMARY

Date	Cum. time hrs:min	Flow gpm	Cum. Flow gals.	Cl_2 Concentration (mg/l) - Grab Sample Column 1 Inf.	Column 1 1 ft	Column 1 Eff.	Column 2 1 ft	Column 2 3 ft	Column 2 Eff.	Column 3 Eff.	Column 4 Eff.	Column (1) press (psi) Inf.	Column (1) press (psi) Eff.	pH (1) Inf.	pH (1) Eff.
11/30/79	0	1.25	-	99.3	0	0	0	0	0	0	0	40	32	7.1	
	1:45	1.3	136.5	99.3							3.5	54	51		
	11:50	0.9/1.3	801.8	145.0		3.5			1.7	7.09	3.5	56	10		
11/31/79 (2)	22:10	1.1	1545.6	12047.0		3.5					3.5	52	12		
12/1/79	37:35	1.5	2740.6									55	52		
	40:45	1.5	3033.7	161		3.5			3.5	3.5	3.5	55	52	6.9	
12/3/79	87:15	1.25/1.5	6870	58	12.4	3.5					3.5	51	49	6.9	
12/4/79	113:00	1.5	9187.5	99.3	46.0	19.5	10.6		2.6	2.6	2.6	54	52		
12/5/79	131:10	1.5	10822.8	60.2	26.6	13.7		4.4	2.6		2.6	52	52	6.2	6.2
12/6/79	151:55	1.3	12565.8	49.6	19.5	5.3		4.4	2.6		2.6	54	50	6.8	6.2
12/7/79	176:25	1.3	14426.8	60.2	29.2	13.2		7.9	4.4		3.5	54	52	6.7	6.5
12/8/79	197:25	1.2	16051.8	67.0	32.0	13.7		8.9	5.3		3.5	52	52	6.6	
12/9/79	214:40	1.1	17242	74.4	37.2	18.2		10.2	6.2		3.1	52	52	6.8	6.6
12/10/79	243:40	0.6	18721	35.5	11.5	8.9		5.3	4.4	3.5	3.5	53	53		
	248:10	0.5	18869.5												
12/11/79	272:25	1.45	20324.5	39.0	10.6	8.0		5.3	4.4	3.5	3.5	52	42	6.2	6.2
12/12/79	284:25	1.5	21674.5	35.4	10.6	7.1		5.3	4.5	3.5	3.5	51	40	6.2	6.2
12/13/79	299:15	1.5	24319.2	60.3	35.5	10.6		8.0	4.5	3.5	3.5	51	40	6.2	5.8
12/14/79	323:40	1.4	26483.7	49.6	26.6	16.2		9.7	5.3	4.4	3.5	53	51	6.6	6.1
	327:40	1.4	26819.7												
12/17/79 (3)	340:40	1.3	27833.7	53.2	28.4	10.6		8.0	5.3	4.4	3.5	52	52	6.8	6.6
12/18/79	363:10	1.5	29709.4	35.4	19.5	10.6		8.0	6.3	5.3	4.4	52	52	6.8	6.6
12/19/79	386:55	1.5	31846.9	24.8	15.9	10.6		7.1	6.2	5.2	4.0	52	52	6.6	6.4
12/20/79	410:40	1.5	33984.4	21.3	13.3	8.1		6.3	5.3	4.4	3.5	52	52	6.6	6.4

(1) Influent Column 1, Effluent Column 1
(2) System Upset
(3) System shut down for weekend

Note:
gpm x 3.785 = liters/min.
gal. x 3.785 = liters
ft x 0.3048 = meters
psi x 0.07 = kg/cm²

APPENDIX B-9. (continued)

Date	Temp. (1) °C Inf.	Temp. (1) °C Eff.	SS (1) mg/l Inf.	SS (1) mg/l Eff.	Phenol (1) mg/l Inf.	Phenol (1) mg/l Eff.	CN_T (1) mg/l Inf.	CN_T (1) mg/l Eff.	SCN (1) mg/l Inf.	SCN (1) mg/l Eff.	TOC (1) mg/l Inf.	TOC (1) mg/l Eff.
11/30/79												
11/31/79 (2)												
12/1/79												
	22											
12/3/79	27		11	6	0.40	0.20	6.8	1	<1.0	<1.0	125	18
12/4/79			16	7	0.90	0.10	0.5	0.3	<1.0	<1.0	90	41
12/5/79			8	6	0.20	<0.01	0.4	0.5	<1.0	<1.0	115	52
12/6/79			10	7	0.30	<0.01	2.7	-	<1.0	<1.0	240	52
12/7/79			14	16	0.30	<0.01	3.7	0.5	<1.0	<1.0	220	80
12/8/79												
12/9/79												
12/10/79			4	15	<0.01	<0.01	1.1	0.3	15	8	194	62
12/11/79			8	7	0.20	0.10	1	1	7.5	2.3	206	56
12/12/79	18	22	8	7	0.25	0.20	0.2	0.2	7.5	<1.0	192	70
12/13/79	22	24	9	11	0.70	0.60	4.6	0.7	6.5	2.5	228	64
12/14/79	25	22	4	13	0.40	<0.01	4.9	1.2	14.0	1.5	270	80
12/17/79 (3)	29	20	26	7	0.70	2.10	11.3	4.4	2.0	10.0	306	120
12/18/79	23	22	18	10	0.60	0.10	11.5	12.6	25.0	15.0	270	156
12/19/79	26	23	0	12	0.60	1.10	6.9	7.1	8.0	8.0	270	105
12/20/79	22	23			1.2	0.2	10.0	6.1	<1.0	<1.0	260	220

(1) Influent Column 1, Effluent Column 4
(2) System Upset
(3) System shut down for weekend
I: Denotes Interference

Note:
gpm x 3.785 = liters/min.
gal. x 3.785 = liters
ft x 0.3048 = meters
psi x 0.07 = kg/cm²

APPENDIX B-10. SODIUM BISULFITE DECHLORINATION-PILOT PLANT DATA SUMMARY

Run No.	Date	Time	Influent data Flow (1) gpm	Influent data pH	Influent data Temp °C	Influent data Cl₂ Resid mg/l	Sodium bisulfite addition ml/min	Sodium bisulfite addition mg/l	Sodium bisulfite addition Bisulfite:Cl₂ ratio	Polymer addition ml/min	Polymer addition mg/l	Effluent data pH	Effluent data Temp °C	Effluent data Cl₂ Resid mg/l	Cl₂ removal %
0	1/7	0920	2.0		37		36	190							
1	1/9	1340	2.0	7.5	32	113.45	36	190	1.67:1	25	3.3	6.6	32	14.18	87.5
		1510	2.0			269.0	36	190	0.71:1					56.00	79.1
2	1/9	1635	2.0	6.5	31	198.2	70	370	1.87:1	25	3.3	6.3	31	0	100
		1720	2.0			170.0	70	370	2.18:1	25	3.3			0	100
		1820	2.0	6.5		184.3	70	370	2.00:1	25	3.3	6.4		0	100
3	1/9	1910	2.0	6.5	31	184.3	52	275	1.49:1	25	3.3	6.4		14.18	92.3
		2145	2.0	7.2		170.16	52	275	1.62:1			6.4		5.32	96.9
3A	1/10	1045	1.3				45	366		15.5	3.1			0	
		1110	1.3			226.1	50	406.5	1.80:1						
		1150	1.3			226.8	50	406.5	1.80:1						
		1545	1.3	6.6		411.0	92	748	1.82:1					744.45	89.6 (2)
		1800	1.3	7.0		7160.0	92	748	0.10:1						
4	1/11	1445	2.0	7.3		140.6	68	360	2.55:1	24	3.2			0	100
		1510	2.0			177.6	68	360	2.02:1					0	100
		1555	2.0	7.0		106.5	68	360	3.37:1					0	100
		1900	2.0	6.4		88.6	68	360	4.05:1	23	3.0			0	100
5	1/12	1005	2.0	6.0	36	141.6	53	280	1.98:1	24	3.0		36	0	100
		1500	2.0	6.3		141.8	53	280	1.97:1	24	3.0	6.1		0	100
		1500	2.0	6.3		141.8	44	233	1.64:1			6.1		0	100
		1915	1.5	6.5		141.6	44	310	2.2:1					0	100
	1/13	1015	2.0	7.2		85.0	44	233	2.7:1			6.75		0	100
6	1/13	1115	2.0	7.2		85.0	29	153	1.8:1	0		6.75		0	100
		1740	1.5			85.1	29	304	2.4:1	23				7.09	91.7
7	1/13	1840	2.0	7.2		85.1	29	153.2	1.8:1	23	3.0	6.9		7.09	91.7
	1/14	1015	2.0	7.1		201.36	29	153.2	0.8:1	23	3.0	6.5		106.35	47.2
		1300	2.0	6.9		443.0	29	153.2	0.35:1	24	3.2	6.5		212.7	52.0
		1440	2.0		33.5								33.5		
		1510	2.0	6.6		127.62	29	153.2	1.2:1			6.5		40.8	68.0
8	1/14	1520	2.0	6.9		127.62	70	370	2.9:1			6.5		40.8	65.0 (3)
		2005	2.0	6.8		70.9	70	370	5.2:1			6.2		0	100
	1/15	0745	2.0	6.8		74.5	70	370	5.0:1	24	3.0	6.4		0	100
		1010	2.0				72	380.5		24	3.0				
		1050	2.0	6.8		290.7	72	380.5	1.3:1					120.5	58.5
		1300	2.0	7.0		141.8	72	380.5	2.68:1			6.5		3.5	97.5
		1615	2.0	7.2		273.0	72	380.5	1.4:1			6.4		56.7	79.2
		2020	2.0	7.0		170.2	72	380.5	2.23:1			6.5		0	100
	1/16	0800	2.0	7.0		177.2	74	391	2.2:1	25	3.2	6.5		0	100
9	1/16	1445	2.0	6.95	41	225.2	74	391	1.53:1			6.5	41	0	100
		1530	2.0	7.8		198.5	73	385.7	1.94:1					0	100
		2140	2.0	7.2		185.0	73	385.7	2.08:1			6.6		0	100
	1/17	0800	3.0				74	257.1		24					
		1000	2.0	7.0		161.65	74	391	2.42:1			6.5		15.6	90.3 (3)

(1) gallons per minute = 3.785 liters per minute.
(2) Invalid data point due to system upset.
(3) Invalid data point due to insufficient reaction time before reading.

APPENDIX C. CHILTON FACTORS USED FOR COST ESTIMATE OF THE VARIOUS TREATMENT PROCESSES

Item number	Item description	Alkaline chlorination	Dual media filtration	Activated carbon	Sodium bisulfite
(1)	Delivered equipment cost	--	--	--	--
(2)	Equipment installation	.4(1)	.4(1)	.4(1)	.4(1)
(3)	Installed equipment cost	(1)+(2)	(1)+(2)	(1)+(2)	(1)+(2)
(4)	Process piping	.3(3)	.3(3)	.3(3)	.3(3)
(5)	Instrumentation	.05(3)	.05(3)	.05(3)	.05(3)
(6)	Capital equipment total	(3)+(4)+(5)	(3)+(4)+(5)	(3)+(4)+(5)	(3)+(4)+(5)
(7)	Building & Site Development				
	outdoor				
	outdoor/indoor				
	indoor	.8(6)	.8(6)	.8(6)	.8(6)
(8)	Auxiliaries (Electrical Item Power)	.2(6)	.2(6)	.2(6)	.2(6)
(9)	Other	.1(6)	.1(6)	.1(6)	.1(6)
(10)	Facilities total	(7)+(8)+(9)	(7)+(8)+(9)	(7)+(8)+(9)	(7)+(8)+(9)
(11)	Total physical plant costs	(6)+(10)	(6)+(10)	(6)+(10)	(6)+(10)
(12)	Engineering and construction	.25(11)	.25(11)	.25(11)	.25(11)
(13)	Contingency & construction	.25(11)	.25(11)	.25(11)	.25(11)
(14)	Facilities & fees	(10)+(12)+(13)	(10)+(12)+(13)	(10)+(12)+(13)	(10)+(12)+(13)
(15)	Total plant cost	(6)+(14)	(6)+(14)	(6)+(14)	(6)+(14)

(n) Indicates Item Number Being Multiplied.

APPENDIX D. TYPICAL COST ESTIMATE UTILIZING CHILTON FACTORS

Item Number	Item Description	Cost^a	Comments
(1)	Delivered equipment cost	$100,000	--
(2)	Equipment installation .4x(1)	40,000	Factor used is at low end of range because some equipment is skid mounted.
(3)	Installed equipment cost	$140,000	--
(4)	Process piping .3x(3)	42,000	Factor used is at low end of range for fluid piping because some equipment is prepiped.
(5)	Instrumentation .05x(3)	7,000	Factor represents minor instrumentation.
(6)	Capital equipment total (3+4+5)	$189,000	--
(7)	Buildings & site development .8x(6)	$151,000	Factor is at midrange for indoor installation.
(8)	Auxiliaries (Electrical Power) .2x(6)	38,000	Factor is at low midrange for a major addition.
(9)	Other .1x(6)	19,000	Factor is near low end of range.
(10)	Facilities Total (7+8+9)	$208,000	--
(11)	Total Physical Plant Costs (6+10)	$397,000	Capital equipment plus facilities.
(12)	Engineering and construction fee .25(11)	99,000	Factor is for simple to moderate complexity.
(13)	Contingency & contractor's fee .25(11)	99,000	Factor is midrange for processes subject to change.
(14)	Facilities & fees (10+12+13)	$406,000	--
(15)	Total Plant Cost (6+14)	$595,000	--

(n) Indicates Item Number Being Multiplied.

a Rounded to the nearest thousand.